The Broadband Bonus:

Estimating Broadband Internet's Economic Value

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Comments welcome.

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Abstract

How much economic value did the diffusion of broadband Internet create? Despite the importance of the question for several national policy debates, no research provides estimates of broadband's incremental contribution to the creation of economic value which are calibrated against historical adoption and factor in counterfactuals. We provide benchmark estimates for 1999 through 2006. We observe $39 billion of total revenue in Internet access in 2006, with broadband accounting for $28 billion of this total. Depending on the estimate, households generated $20 to $22 billion of the broadband revenue. Approximately $8.3 to $10.6 billion was additional revenue created between 1999 and 2006. That replacement is associated with $4.8 to $6.7 billion in consumer surplus, which is not measured via Gross Domestic Product (GDP). An Internet-access Consumer Price Index (CPI) would have to decline by 1.6 percent to 2.2 percent per year for it to reflect the creation of value. These estimates differ from conventional wisdom by an order of magnitude and alter several policy debates.

I. Introduction

Dial-up Internet access became available from commercial providers in the 1990s and in less than a decade diffused to more than half of U.S. households. Broadband emerged later as a higher quality and more expensive alternative for delivering Internet access, and at the end of the 1990s was available in only a few places and from a limited set of providers. In September 2001 approximately 45 million U.S. households accessed the Internet through a dial-up connection, while only 10 million used a broadband connection.[1] Broadband became more reliable and more widely available thereafter, and, consequently, many households paid to upgrade their Internet service. By March 2006 approximately 47 million households (and growing) had broadband connections, while 34 million (and declining) used dial-up.[2]

The upgrade to broadband motivated several interrelated policy debates. At the start of the new millennium, the Federal Communication Commission (FCC) adopted a set of policies designed to give telephone companies incentives to build broadband access to homes, which cleared U.S. Supreme Court review in 2005. In the latter part of the decade, the U.S. Congress added billions of dollars in rural broadband subsidies to the American Recovery and Reinvestment Act, popularly known as the Stimulus Bill, which was passed in February 2009. In the same month, Congress authorized the FCC to write a National Broadband Plan, which touched on universal service policy and competition policy for broadband in the United States. It was released in March 2010.

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[1] NTIA (2004) is the source for these statistics.
[2] See Horrigan (2007) at http://www.pewinternet.org/.

All three policy initiatives were based on a belief about the high economic value created through the replacement of dial-up access with broadband. These conclusions came from reports and white papers funded by stake-holders (reviewed below). Many of the reports were not founded on firm statistical footing, nor did any of them calibrate their estimates against actual broadband diffusion. As a result, prior research does not provide an appropriate estimate of broadband's effect on the U.S. economy.

This is the first study to fill this gap. We address the two related economic questions that arise in all prior policy studies: (1) how much surplus did the building of broadband create for household users of broadband Internet access, and (2) what were the private incentives for building broadband?

Our estimates are as follows. While broadband accounted for $28 billion of GDP in 2006 (out of $39 billion in total for Internet access), we estimate that approximately $20 to $22 billion was associated with household use. Of that amount, we estimate that broadband's deployment created approximately $8.3 to $10.6 billion of new GDP. In addition, between $6.7 and $4.8 billion constituted new consumer surplus. In both cases, this is above and beyond what dial-up would have generated. The newly created GDP is between 40 percent and 50 percent of measured total GDP, while consumer surplus (which is not measured) is between 31 percent and 47 percent of the newly created GDP.

By one yardstick these estimates are very low, and by another, very high. Our findings are much lower than those found in typical stake-holder funded policy analysts and lobbyist reports, which regularly estimate the benefits from broadband in the range of hundreds of billions of dollars. We conclude that existing reports used inappropriate methods and outdated data, leading to outsized estimates that stretched beyond plausibility. At the same time, official U.S. government statistics trend in the opposite direction. For example, the CPI for Internet access does not include an adjustment for the broadband upgrade. We conclude that Internet-access price indices would have had to decline an additional 1.6 percent to 2.2 percent per year to account for the consumer benefits generated from merely upgrading to broadband.

Our estimates also identify the sources of the private incentives to upgrade. The role of regulatory incentives has received the most attention in the prior literature.[3] We show how several additional factors, such as the identity of the producer, the size of potential business stealing and cannibalization, and the speed of household willingness to respond to new options, played a role. Our findings suggest that these other economic factors were as significant as regulatory incentives.

While this study is motivated by contemporary policy debate, it aims at a much broader agenda—basing U.S. broadband policy on economic reasoning and transparent statistical approaches. The study stresses how to apply economic reasoning to a question to which it has not been applied until now. The analysis exposes the importance of specific assumptions, identifies precisely where other estimates went wrong, and focuses attention on areas that require improvement and more precision. In this sense, the study addresses one of the priorities outlined by Flamm, Friedlander, Horrigan, and Lehr

[3] For an overview, see Goldstein (2005), Neuchterlein and Weiser (2005), Greenstein (2008), and Hazlett and Caliskan (2008).

(2007), who examined the poor state of U.S. statistics for the Internet and called for developing a new research agenda.[4]

Our paper is organized as follows. In Section II, we briefly discuss prior work and how our approach differs. In Section III, we review standard statistics about the diffusion of Internet access between 1999 and 2006. In Section IV, we discuss the data we collect. In Section V we estimate the value created by the diffusion of broadband. Finally, in Section VI, we conclude with an assessment of future directions for policy discussions.

II. Policy and the Economic Benefits from Broadband

Motivation for this study comes from a decade of policy discussion prior to the National Broadband Plan, which employed inappropriate conceptual and measurement approaches for assessing the economic gains from broadband. Despite its importance, there has been no research accounting for Fogel's counterfactuals. Research does not clearly define what is included in those estimates and what should be considered an externality. There has been no research calibrating the estimates against actual historical adoption. Our study is the first to do all of the above.

How did policy arrive at conclusions so far from what appropriate economic analysis would suggest? Here we provide a brief history of influential policy research in communications just before and after the turn of the millennium. By influential research we mean research aimed to shape competition policy or universal service policy inside

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[4] Flamm, Friedlander, Horrigan, and Lehr (2007) focus on a wide range of issues, such as measuring productivity and assembling new data to accommodate novel online economic behavior. The primary goal of our paper is to dig deeply into one aspect of this broad agenda.

Washington, D.C., primarily at the FCC or the U.S. Congress. We focus on the few studies that tried to derive its value and show where they are far out of scale with economic reasoning.

One study, Crandall and Jackson (2003), set the stage for later efforts. The authors undertook to forecast the gains from deploying broadband before most of it had even been deployed. Though eventually published as a chapter in a book in 2003, a working paper circulated earlier in July 2001. It continues to be the most cited version.[5] Crandall and Jackson wrote their paper when less than 10 percent of households had adopted broadband, and before any other researcher had made a forecast. The paper clearly states that the estimates are a *forecast*, and the authors provided appropriate guidance about the factors shaping their forecast.

Their paper is titled "$500 Billion Dollar Opportunity." The figure in the title is an estimate at the upper range of their forecast of the potential gains from deploying broadband. A few years later, Crandall (2005) cited the same Crandall and Jackson study, pegging the gains at $300 billion, which lay in the middle of their forecast. What factors went into this estimate? Crandall and Jackson emphasized something they call "direct" and "indirect benefits," calculating consumer and producer surplus for the former, and a range of other factors for the latter. With the benefit of hindsight, it is possible to see why the forecast was too high.

Most significantly for our analysis, the forecast was biased upward because the authors failed to account for the argument made by Fogel (1962). Though Crandall and

[5] For example, see http://www.att.com/public_affairs/broadband_policy/BrookingsStudy.pdf.

Jackson cited Fogel's study in their appendix, they did not account for Fogel's counterfactual in their calculations, namely, what would have occurred in the absence of the deployment of broadband.[6] Not including the counterfactual gains from continuing with dial-up in the analysis was equivalent to assuming dial-up would not have provided many valuable functions that broadband also contributed, such as carrying email and enabling Web browsing. Without accounting for this counterfactual, the value of broadband's economic contribution was biased upward.

A few others components of the $500-billion-dollar were also too optimistic, adding an upward bias. First, Crandall and Jackson forecast a "direct" gain to consumers from subscription services of $150 to $225 billion dollars. The estimate was far higher than what has actually occurred. It implied a very high willingness to pay for broadband Internet access above and beyond dial-up Internet access. In practice, evidence about consumer willingness to pay for broadband indicates that it is much lower (Savage and Waldman, 2004). We will say more below, suggesting the gains are two thirds lower.

Second, the authors presumed broadband would create additional value related to entertainment for consumers in the range of $77 to $142 billion. To benchmark that value Crandall and Jackson used the gains experienced from cable and DBS entertainment services.[7] This aspect of the forecast also has not happened. Though broadband Internet

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[6] Fogel (1962) and related studies famously illustrated the problem with not including the counterfactual in the contribution of railroads to economic growth in the United States in the mid-nineteenth Century. Fogel stressed that examination of the railroad economy by itself is misleading because significant economic growth would have occurred without railroads, even with an extensive canal system.

[7] "It is reasonable to assume that eventually the contribution to consumer surplus of new video and other entertainment options created by widespread diffusion of broadband Internet access would be at least as great as that already created by cable television and direct broadcast satellites. This provides us with an estimate of $77 billion to $142 billion per year;" pp. 174-75 of Crandall and Jackson (2003), corresponding to pp. 37-38 of the working paper.

has enabled considerable variety of entertainment, most of it has not generated additional revenue beyond subscriptions for Internet access, nor has there been dramatic change in the variety of content viewed by dial-up adopters (Hitt and Tambe, 2007).

A generous interpretation of Crandall and Jackson might include the additional revenue generated by advertising, which supports much of the new information services, news services, blogs, and other Web2.0 sites created in the first decade of the new millennium. In that case, with the benefit of hindsight it is possible to see that this aspect of their forecast was merely overoptimistic by several orders of magnitude. Online advertising generates several tens of billions of dollars at most.[8] In any case, these services cannibalized existing advertising-supported media, so broadband's economic contribution had to net out the counterfactual. There was simply no way for it to amount to even half of $70 billion unless the increase in consumer surplus generated (over what dial-up would have created with similar technologies and what would have occurred offline anyway) was much higher than the value of the advertising revenue. We believe that the number was much smaller.

These two components reduce the estimates by half. To illustrate, if we say the first component was $50 billion and the second was $30 billion, then Crandall and Jackson's estimate would be reduced by as little as $147 billion, or half of the middle forecast, and as much as $287 billion, which is more than half of the highest forecast.

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[8] The dominant online advertising company, Google, can illustrate why entertainment advertising revenue cannot add up to more than $10 to $20 billion. Google alone makes just over $22 billion a year in revenue, with approximately two thirds of that coming from AdWords, the auctioning of words to advertise next to search activity. Approximately one third comes from AdSense, the Google effort to sell advertising to third party sites, such as news, entertainment, and blog sites. The second largest online advertiser, Yahoo!, is also small, with ad revenue less than $7 billion. There is simply not enough revenue to add up to a large entertainment benefit to advertisers.

That is before we get into other components of Crandall and Jackson's forecast. For example, the authors forecast that broadband would enable widespread use of Voice over Internet Protocol (VoIP), which would lead to huge savings in telephone expenditure. Though VoIP has become available and been adopted (especially for overseas phone calls), the expenditure savings have not reached the forecast levels. Moreover, the reduction in use of wireline telephone service has occurred (as forecast), but this is largely due to substitution by wireless handsets, not the diffusion of broadband.

Starting from this flawed forecast, the policy conversation in Washington, D.C., began to focus on something far from any sensible economic benchmark. Virtually every analysis that followed Crandall and Jackson lacked correction for Fogel's point. In addition, many later analysts retained the direct/indirect distinction even though the precise definitions drifted. Perhaps more surprisingly, no later analysis challenged the range of estimates in Crandall and Jackson, even though contemporary experience should have suggested the forecast needed updating. For example, numerous surveys in the middle of the decade conducted by the Pew Research Center's Internet and American Life Project found no dramatic changes in Web use following the deployment of broadband, as should have been expected if broadband's economic benefits were as enormous as several hundred billion dollars.[9] While researchers at Pew openly challenged conventional wisdom and exaggerated claims in some areas other than the economic

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[9] The only major change was due to an increase in music downloading in households with children. Surveys simply did not find large changes in allocation of household time until Web2.0 took off, which was well after the entry of YouTube (begun in April 2005), MySpace (begun in August 2003), and Facebook (which launched a high school service in September 2005). See http://www.pewinternet.org/.

value of broadband, they did not challenge the range of the forecast. This is just one of many examples.

Perhaps even worse, near the end of the decade new policy research emerged and it no longer claimed to be a forecast, and it no longer employed methods as carefully as Crandall and Jackson. For example, in 2008 a very visible and well-funded group, Connected Nation, pegged the benefits from national deployment of broadband in *only* rural areas at $134 billion.[10] Connected Nation's report did not include Fogel's point. It assigned all the benefits of the Internet to broadband, as if dial-up conferred no such gains and was not available in rural areas, which was plainly false.[11] Connected Nation's report also obliterated the boundary between "direct/indirect" benefits, as well as externalities and the private willingness to pay and supply a service. The analysis included numerous other errors.[12] Despite those errors, it received considerable attention in policy discussion.[13]

These and related inaccuracies continued in the discussions prior to the National Broadband Plan. The omission of Fogel's point was particularly common, even in reports that were generally well regarded and polished. One of the best reports published at the time, for example, was Atkinson, Ezell, Andes, Castro, and Bennett (2010), which was sponsored by a prominent and prolific Washington based think tank, the Information

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[10] "The Economic Impact of Stimulating Broadband Nationally," Connected Nation, 2008. See http://connectednation.org/.

[11] In fact, dial-up had been available in such areas since the late 1990s (Downes and Greenstein, 2002).

[12] Perhaps most egregiously, it used estimates of the growth brought about by broadband in urban areas to estimate broadband's impact in rural areas. Such estimates did not control for endogeneity of investment or for the forecasting error that result from projecting far out of sample.

[13] *Connecting America, The National Broadband Plan,* http://www.broadband.gov/

Technology and Innovation Foundation. It was a widely cited and well-publicized report about the twenty-fifth anniversary of the establishment of the dot-com economy, and included a long discussion about changing online behavior and gains in firm productivity. The review was thorough and cited dozens of studies. However, when the report turned to the economic benefits from broadband, it used the same flawed economic reasoning as others. It concluded with a section on page 51 about the "Direct Contribution of the Internet Industry to the Economy," and offered no precise definition for the contribution of broadband over the counterfactual. Instead, it focused on the size of GDP affiliated with broadband. The omission of Fogel's point left the impression that broadband is responsible for hundreds of billions of dollars of GDP.[14]

Our main point is that the scale of a misleading forecast had a much longer life in Washington, D.C., than it should have. Policy conversations continued to quote the $500 billion figure as if it had been realized. This conventional wisdom went unchallenged well into fall 2008 and winter 2009, when discussion leading to the Stimulus Bill proposed tens of billions of dollars for broadband build-out in low-density areas, and brought additional attention to the question of broadband's economic value.[15] To our

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[14] For example, Atkinson et al. (2010) quotes a study commissioned by the Interactive Advertising Bureau (IAB, 2009) about the size of the online economy as evidence that broadband makes a large contribution to economic activity. It does not adjust IAB's accounting for the incremental contribution of broadband. There are dozens of such adjustments needed, and, yet, there is no hint of this issue in the discussion. For example, revenues at United Parcel Service make up a piece of the IAB estimates for the size of the economic activity supported by electronic commerce. That estimate does not help understand broadband's contribution to the economy. Atkinson, et al. (2010) would have had to recognize that many of the same shipments would have occurred with dial-up electronic commerce as they did with purchases made over broadband lines. Not doing so leads to an upward bias in the estimate of broadband's contribution.

[15] We know about these quotes from personal experience. A working paper version of this study was initially presented in Washington, D.C., at the Telecommunications Policy Research Conference in late September 2008. It raised doubts about the common assumptions and the scale of the common forecast.

knowledge, only one prominent report did not repeat these errors, and that was the National Broadband Plan itself, released in March 2010. In part this was due to the circulation of a working draft of the present study, which began to circulate prior to the plan's writing.[16]

Despite the high stakes, this misleading view survives because nothing sensible has replaced it. Two key questions have yet to be addressed. First, what is the increase in producer surplus (GDP) affiliated with the diffusion of broadband beyond what would have been generated had dial-up continued? Second, what is the increase in consumer surplus beyond what would have occurred had dial-up continued? We will show how to address these questions with appropriate economic analysis, and make the answer consistent with historical record. In the process, we will follow convention and not worry about *which* vendor or user gains or loses; rather, we will only compute an aggregate measure. The only exception we will make is in the analysis of incentives, to stress the difference between cable and phone companies.

The prior policy literature also remains confused about the "direct and indirect" economic effect. A more precise approach uses long-standing microeconomic reasoning, measuring the economic factors considered by the parties involved in a transaction—in this case, anything that shapes the perceived or anticipated costs and benefits of using dial-up or broadband. More precisely, broadband is one of many components in a

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Well into winter 2009, the authors continued to present this work and continued to confront statements by numerous reporters, lobbyists, and industry analysts that the scale of the gains from broadband deployment reached to the hundreds of billions of dollars. Upon further questioning, most of those who made these statements were quoting Crandall and Jackson's forecast, and many did not know they were quoting a forecast, not actual measurement.

[16] In particular, see the earlier version of this paper, NBER Working Paper 14758, which was released in February 2009, http://www.nber.org/papers/w14758.

network delivering value to end users. The other inputs include components such as software, personal computers, hosting services, content creation, content aggregation, electronic retailing services, search services, and so on. The parties involved in a transaction for broadband Internet access can anticipate some incremental value from that transaction, while the externalities are benefits or costs not considered.

For example, we assume the following factors shape revenue for suppliers: sale of second lines, revenue for dial-up access, and revenue for broadband access. This definition also puts a boundary on externalities. For example, a standard economic interpretation includes plenty of sales to any supplier involved in a transaction, such as a cable company or phone company. Externalties only pertain to suppliers who are not suppliers to cable or phone companies, such as Netgear, which sells more Wi-Fi equipment to broadband households than dial-up households; Amazon, which makes additional sales because broadband users experience more-satisfying service; or Google, which makes more incremental advertisement sales because users stay online longer.

Similarly, our interpretation does include benefits that users anticipated. The following factors shape the anticipated value of broadband service and, hence, the willingness to pay for an upgrade: savings on a second line, anticipated savings on commute time, anticipated health and entertainment benefits, and anticipated savings on phone bills. Externalities are factors that would be unanticipated or unperceived costs or gains. We can plausibly think of several related mechanisms that would produce both positive externalities (e.g., unanticipated information) and negative externalities (e.g., online fraud). These externalities are not part of the calculation.

Consistent with these definitions, we calculate net private gains in revenue in time *t* as follows: net gains (*t*) = broadband rev (*t*) – lost dial-up rev (*t*) – lost second-phone-line rev (*t*). To calculate net private gains in consumer surplus in time *t* we calculate the following: net gains (*t*) = willingness to pay for broadband over dial-up (*t*) – broadband revenue (*t*) + adjusted savings on second-phone-line rev (*t*). The research challenge is to calibrate the value for each year against the actual history of broadband adoption in the United States. This is the exercise that no research has done.

III. Measuring Broadband Services

The diffusion of dial-up coincided with the initial use of the Internet in most households. Broadband was available in only a few locations in the 1990s and the early 2000s, but it became more available over time. Many households adopted it thereafter.

Broadband service was delivered to households primarily in two forms of wire-line service—over cable or telephone lines. The former involved a gradual upgrade to cable plants in many locales, depending on the generation of the cable system.[17] The latter involved upgrades to telephone switches and lines to make it feasible to deliver a service called *digital subscriber line* (DSL). Both of these choices typically supported higher bandwidth *to* the household than *from* it—called *asymmetric digital subscriber line* (ADSL) in the latter case. Some cable firms built out their facilities to deliver these

[17] In many areas, households also had access to direct supply of high-speed lines, such as T-1 lines. This was prohibitively expensive for almost all users except businesses, and even then, it was mostly used by businesses in dense urban areas, where the fiber was cheaper to lay. Fiber to the home has recently become cheaper, and may become a viable option sometime in the future. See Crandall (2005). During the 1990s most cable companies sold access to the line directly to users, but made arrangements with other firms, such as Roadrunner or @home, to handle traffic, routing, management, and other facets of the user experience. Some of these arrangements changed after 2001, either due to managerial preferences, as when @home lost its contract, or due to regulatory mandates to give users choice over another Internet Service Provider (ISP), as occurred after the AOL/Time Warner merger. See Rosston (2009).

services in the late 1990s, and many—especially telephone companies—waited until the early to mid-2000s.

Broadband has several appealing features. In comparison to dial-up service, broadband provides households with faster Internet access and better online applications. In addition, broadband services are also "always on," and users perceive that as a more convenient service.[18] Broadband also may allow users to avoid an additional phone line for supporting dial-up.

Many factors shape the quality of a user's experience, such as the capacity/bandwidth of lines, the number of users in the neighborhood in a cable system, the geographic location of a system in the national grid, the frequency of use of sites with geographically dispersed caching, and the time of day at which the household performs most activities. In brief, generalizations are hard to make beyond the obvious: broadband gives the user a better experience than dial-up access.[19]

Figure 1 provides a summary of the federal government's efforts to collect data about Internet adoption.[20] The first questions about broadband use appeared in 2000 and showed a growth in adoption, peaking at close to 20 percent of households in 2003, when

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[18] Surveys show that a maximum rate of 14.4K (kilobytes per second) and 28.8K were predominant in the mid-1990s for dial-up modems. The typical bandwidth in the late 1990s was 43K to 51K, with a maximum of 56K. DSL and cable achieved much higher maximum bandwidths, typically somewhere in the neighborhood of a maximum rate of 750K to 3M (megabytes per second), depending on the user choices and vendor configuration.

[19] Download speed may not reach the advertised maxima. In cable networks, for example, congestion issues were possible during peak hours. In DSL networks, the quality of service could decline significantly for users far away from the central switch. The results are difficult to measure with precision.

[20] The first government surveys of household Internet adoption date back to 1997. These came from additional questions in the CPS supplement, which had added questions about household use of personal computers in 1995 (see NTIA, 1995). These were continued with surveys in 1997, 1998, 2000, 2001, and 2003 (see NTIA, 2004). The survey was stopped after 2003, then reinitiated in 2007. The latest data are not available, as of this writing. CPS supplement surveys prior to 1997 also examined PC use at home, but asked about use of generic online services, such as CompuServe, not Internet access. For simplicity and consistency, we stick with Figure 1.

these surveys were discontinued for some time.[21] Recent data about household use, collected by the Pew Internet and American Life Project, show that diffusion continued in the anticipated direction, accelerating somewhat.[22] Notably, adoption reached more than 47 percent of households by 2006. We will discuss this data in more detail below. Table 1 provides the FCC's efforts to measure the deployment of broadband lines.[23] It tells the same story as Figure 1, but from the vendor-side of the market: vendors were increasingly deploying broadband lines, presumably to meet growing household demand.

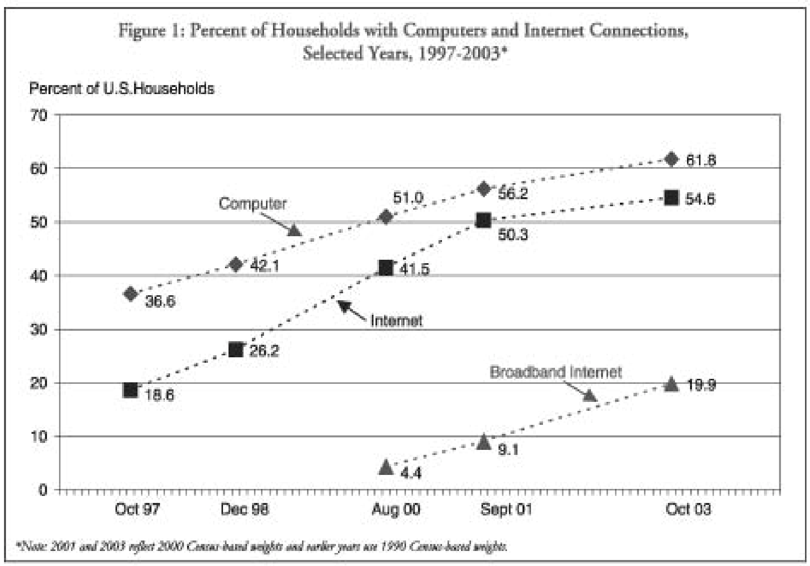

Figure 1: Percent of Households with Computers and Internet Connections, Selected Years, 1997-2003*

*Note: 2001 and 2003 reflect 2000 Census-based weights and earlier years use 1990 Census-based weights.

There are no revenue estimates for household broadband services, but we can place a bound on an estimate for the combination of household and business revenues. The U.S. Census Bureau estimates revenues and publishes these in its *Annual Service*

[21] The descriptive results were published in reports authored by staff at the NTIA. See NTIA (2004).

[22] See http://www.pewinternet.org/.

[23] The FCC has never asked about deployment of dial-up. It also has never asked about the prices of broadband.

Survey. Table 2 provides an adjusted summary of these reports (see Appendix).[24] We expect that between 60 percent and 75 percent of the revenue in Table 2 came from households, depending on the year and access mode.[25] The growth in revenues in Table 2—from $5.5 billion in 1998 to $39 billion in 2006—is astonishing for an entirely new market, especially one that did not start growing quickly until after 1995. Broadband revenues comprise approximately half the total revenue over the eight years, beginning with less than 6 percent in 1999 and growing to 72 percent of the total revenue in 2006.

TABLE 1 Residential broadband deployment, 1000s of households

Year	1999	2000	2001	2002	2003	2004	2005	2006
DSL	291.8	1,594.9	3,616.0	5,529.2	8,909.0	13,119.3	17,371.1	20,143.3
Cable	1,402.4	3,294.5	7,050.7	1,342.5	16,416.4	21,270.2	24,690.0	27,720.4
Satellite	50.2	102.4	195.0	257.0	341.9	422.6	529.4	1,839.4

Source: Federal Communications Commission.[26]

These revenue levels are important to stress, because access fees generated most of the revenue during the first decade of the commercial Internet. The typical household

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[24] The adjustments are for changes in sampling frame; the Census does not return to historical estimates and review the sampling frame of prior estimates to make all the estimates consistent over time.

[25] We came to that estimate by the following means: First, our estimates below suggest household revenue for the Internet overall makes up 70 percent to 75 percent of the total revenue. Second, the FCC broadband deployment report puts the number of broadband lines to households at roughly two-thirds of the total number of lines deployed. Since revenue per line for business likely exceeds that for households, it is plausible that household revenue is closer to 60 percent of total revenue. See Table 13: High Speed Services for Internet Access at http://www.fcc.gov/wcb/iatd/comp.html. Hence, in the text we say "60 percent to 75 percent." Note that Table 1 and 2 are not comparable, since Table 1 is for households only, while Table 2 is for households and businesses.

[26] See http://www.fcc.gov/wcb/iatd/comp.html, *Broadband Reports*, Table 3, for precise definitions. This table covers any line with at least 200kps in *either* direction.

spent more than three-quarters of its time online at free or advertising-supported sites, devoting most of its Internet budget to access fees, not subscription fees.[27] Although subscription-based services and advertising services have started growing rapidly after 2003, the amount spent on access fees each year far exceeds advertising revenue. Advertising revenue is now growing at a more rapid pace than subscription fees, and it may exceed access revenue soon, but not as of this writing.[28]

TABLE 2 Adjusted revenue for access markets (millions of dollars)

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006
Dial-up	5,499	8,966	12,345	13,751	14,093	14,173	14,081	12,240	10,983
DSL		228	1,245	2,822	4,316	6,954	10,240	12,034	15,066
Cable modem	138	274	903	2,600	4,117	7,372	9,435	11,139	13,156
Wireless							668	1,140	

Source: Census Annual Surveys. See Appendix for adjustments.

IV. Data

In Table 3 we summarize the data used to compute these numbers. Broadband revenue comes directly from data about the actual diffusion of broadband. We estimate lost dial-up and second line revenue by calibrating these against broadband adoption. In addition, we consider different assumptions about pricing and about the rate at which dial-up users became broadband users/converts. Estimates of the willingness to pay for broadband

[27] See Goldfarb (2004).

[28] The following will provide a sense of the magnitudes of different activities. In the *2006 Annual Service Survey*, Web search portals (NAICS 518112) generated $6.3 billion in advertising in 2006, out of $9.1 billion in total revenue. This is up from $4.5 billion and $3.3 billion in advertising revenue in 2005 and 2004, respectively. In addition, Internet publishers (NAICS 516) generated $2.6 billion in revenue in 2006, up from $2.3 billion and $1.8 billion in 2004 and 2005, respectively. That is still far less than the $39 billion in access revenue in 2006.

(beyond dial-up) come from Savage and Waldman (2004). We say more about the sources now.

IV.i. Adoption of the Internet

To derive the total number of adopters, we estimate the percentage use of dial-up and broadband technologies across all households and then multiply this percentage of adopters by the total number of households.[29] Data about household use of dial-up and broadband Internet comes from two sources, the NTIA (National Telecommunications and Information Administration) and Pew. [30] We use the NTIA estimates through 2003 and use the Pew estimates thereafter. Pew's data are good for measuring adoption, but incomplete for measuring price and quality.[31] Data about total number of households come from the U.S. Census estimates.

TABLE 3 Household Statistics, 1999–2006 (MM)

Year	1999	2000	2001	2002	2003	2004	2005	2006
Total Households	105.0	106.0	107.0	108.0	109.0	110.0	111.0	112.0
Total Internet Adopters	35.5	44.0	53.8	56.7	59.5	66.0	73.3	81.8
Total Broadband Adopters	0.9	3.2	9.6	13.0	18.5	27.5	41.1	47.0
Total Dial-up Adopters	34.5	40.8	44.2	43.7	41.0	38.5	32.2	34.7
Total Second Phone Lines	23.6	26.2	26.3	18.4	16.0	13.8	12.1	10.5

Sources: See text.

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[29] We prefer this because it builds on surveys of users rather than estimates of broadband deployment, such as those kept by the FCC. That choice does not matter until the end of the sample. While the FCC numbers do not differ much overall from Pew's, they do differ recently. We prefer the Pew data because it is consistent with the data from the NTIA, and surveys of users also inform us about other relevant factors for measurement, as will become clear in the discussion.

[30] For years between 1997 and 2003 when we have no direct observation, we interpolate between the two closest known measures of adoption percentage with a target towards midyear.

[31] Pew's surveys were supervised by John Horrigan. The surveys ask a variety of questions, most recently including questions about bandwidth, prices, and use, but did not get complete answers. For example, 80 percent of respondents did not know the bandwidth of their broadband in the 2005 survey. John Horrigan, private communication (July 2008).

IV.ii. Second Lines

Table 3 provides estimates of the total number of households in the United States with at least one second line. We gathered this from FCC reports, which do not break out second-line use into its primary purpose.[32] Prior research has shown that several factors determined the growth of second lines in the 1990s, including use of the Internet.[33] The growth and decline in households with second lines is highly correlated with the growth of dial-up Internet access and its replacement with broadband lines.[34] For example, in the latter part of the 1990s, the use of second lines grows from 11.4 percent in 1994, to 26.3 percent in 2001. It declines after 2001—from 26.3 percent to 10.5 percent in 2006.[35]

These trends put bounds on estimates of the second lines supporting Internet dial-up. For example, 16 million households had an active second line in 2003, a decline from 18.4 million in 2002. The 2.4 million drop in second phone lines represents the upper bound for dropped lines by broadband adopters, meaning that a maximum of 53 percent of dial-up converts dropped a line that year.[36] More broadly, that percentage varies between 2002 and 2006, rising no higher than 53 percent and falling no lower than 25 percent.[37]

In our base specification, we reduce the volatility in the estimates from the role of second lines. Specifically, we assume that one-third of broadband adopters drop a second

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[32] See the FCC's 2007 *Trends in Telephone Service*, Table 7.4: Additional Residential Lines. This is the most recent available data as of this writing. It is available at http://www.fcc.gov/wcb/iatd/trends.html.

[33] See Duffy-Deno (2001), and Eisner and Waldon (2001).

[34] The other primary driver of the decline in second lines is the growth of cell phone use.

[35] 2006 is the last available year, as of this writing.

[36] Strictly speaking, the upper bound could be larger if more than 2.4 million broadband adopters dropped a second line at the same time others were adding lines, since we observe only a net change.

[37] In other years, we get different percentages, and prior to 2002 there is no decline in use of second lines one year to the next.

line between 2002 and 2006, while we will assume no broadband adopter drops a second line between 1999 and 2001. That results in the right level of dropped second lines by 2006, but we view this as a conservative approach (i.e., a deliberate undercount).

A second telephone line can cost a household as little as $16 a month in some cities and as much as $24 before including per-minute usage charges, which are generally low. For our simulations, we use an average of $20.

IV.iii. New Users and Converts

Neither the NTIA reports nor the Pew reports provides statistics for each year about whether new broadband adopters are new Internet users or converts from dial-up. At first there was good reason for this lack of information; there was no question that virtually all household broadband adopters had experience with dial-up before upgrading. Some new users, however, moved directly to broadband in later years. In his report describing adoption behavior in the Pew survey between 2005 and 2006, John Horrigan, the Pew researcher who analyzed the results, mentions that new Internet users comprised a large percentage of the adopters of broadband that year.[38] He did not mention this for earlier periods because it simply was not a significant factor until then.[39]

Those facts help pin down several assumptions about conversions. We have no way to know the rate of conversions precisely since public surveys only ask about total adoption in a given year, not any yearly tally of new Internet users. Yet, we are certain

[38] Horrigan does highlight that few adopters of broadband went straight to broadband without first using dial-up. Horrigan also states that 4 (out of 8) million broadband adopters were new users of the Internet between 2005 and 2006, and never before had Pew's surveys found a percentage anywhere near that high. See http://www.pewinternet.org/.

[39] Horrigan, private communication (July 2008).

that the vast majority of the broadband adopters between 1999 and 2004 were former dial-up users, and we are not so confident about the same fact in more recent years.

For our baseline specification we will assume that 100 percent (all 10 million households) are converts in 1999-2001. There are approximately 37 million additional adoptions in 2002-06, with 31 million of those occurring prior to 2005. The number of new users finally becomes large enough to notice near the end of our sample, but cannot exceed 50 percent of the 6 million adopters in 2006, and, to remain consistent with Horrigan's observation, it must be less than 50 percent of the 14 million adopters between 2004 and 2005. In other words, we assume that 10 million new Internet users among broadband adopters is too high a number, and 3 million is too low. For lack of a better number, we will split the difference and assume 7 million in our baseline specification, then test alternatives assumptions. Our baseline, therefore, estimates that 30 million broadband adopters between 2001 and 2006 were converts from dial-up. For convenience, we will assume an 81 percent conversion rate for 2002 through 2006 (instead of concentrating it all in 2005 and 2006).

To test the importance of this assumption, we calculate implausible extreme bounds (81 percent convert rate and 100 percent convert rate for all years). These bounds will move estimates in a predictable direction, but result in outcomes outside a plausible range, so they show how this assumption affects the final estimation. Below, in rows three and four of Tables 4, 5, and 6, we provide a summary of such extreme bounds in comparison to our benchmark estimate.

IV.iv. Price Levels

We do not observe prices directly. Consistent with the generally reported patterns for nominal prices and for simplicity, we assume for all of our simulations that price is unchanging over time, and we set the average price level for dial-up at $20.[40] We choose that price because it is the reported average dial-up price for users in two CPS supplements in the 1990s.[41] We assume the average price for broadband is either $36 or $40, depending on the simulation we conduct. Again, this is consistent with reported price levels in Pew reports and other research.[42]

V. Benchmarks

We begin with estimates of the revenue generated by broadband and then consider estimates of consumer surplus. Following that, we provide an estimate of an equivalent price index. Throughout, we try to maintain a conservative approach and show how a range of assumptions alter the qualitative results. To be clear, when we vary parameters we are not estimating demand; rather, we are holding fixed the known facts about broadband's deployment (i.e., Table 3) and are learning how changes to key assumptions

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[40] We could examine the effect from small price fluctuations. We do not do so below, since, for obvious reasons, the qualitative results change things very little.

[41] It is also the median price in Savage and Waldman (2004) and Stranger and Greenstein (2007). The CPS supplement asked about monthly expenditure (which looks close to monthly prices) in only two years and not thereafter. The consumer expenditure survey, however, continued to ask about online expenditures for Internet services every year. While it is not a price index, it looks close to prices (but does not distinguish between use of broadband and dial-up until after 2001). The difference between some expenditure and none is a good indicator of a household's use of the Internet, and correlates with changes in other levels of expenditure for related goods, such as music and videos, as well as other forms of entertainment (see Hong, 2007).

[42] For U.S. price quotes, see Savage and Waldman (2004), Chen and Savage (2007), Crandall, Sidak, and Singer (2002), Rappoport et al. (2003), and Flamm and Chadhuri (2007).

about the underlying features of diffusion alter inferences about consumer surplus and new revenue generation.

Throughout we maintain the comparison between broadband and a counterfactual, namely, what would have been supplied by dial-up in the event that broadband had not arisen. We keep this counterfactual straightforward: for example, we do not consider endogenous technical change, such as how other complementary services might have changed (e.g., music or video downloads) had the counterfactual technology (dial-up) remained dominant and un-replaced by broadband.

V.i. Creation of New Revenue

We begin with a calculation of a single year, 2003, to illustrate how we provide a full accounting of the new revenue affiliated with broadband. In the process of explaining a single year, we will articulate the principles that apply to all years.

Because the average price of residential broadband access was somewhere between \$36 and \$40 a month in 2003, residential broadband generated an annual revenue of somewhere between \$8 billion (\$36/month × 12 months × 18.5 million households) and \$8.9 billion (if the price is \$40/month).

We first estimate how many broadband users formerly used dial-up. On the basis of our previously stated assumption that with an adoption rate of 81 percent, 30 million users of broadband were converts, the new adopters of the Internet (not converts) generated between \$455 million of revenue (if the price was \$36) and \$505 million of revenue (if the price was \$40) in 2003. Converts—those who switched from dial-up—generated between \$1.9 billion and \$2.1 billion.

We next calculate the proportion of revenue generated by dial-up converts that was cannibalized, that is, when the revenue source changed while staying within the same firm. If the average price of dial-up Internet access was $20 a month, it would account for $1.1 billion of cannibalized revenue. That is not all, however. In addition to the loss of dial-up revenue, there was a loss of revenue from retired second phone lines, with which many households had supported their dial-up Internet. Using 2003 as an illustration once again, newly retired phone lines from dial-up converts amounted to a loss of $357 million in revenue for phone companies in 2003. That puts the total opportunity cost of lost dial-up revenue and second-line revenue at $1.4 billion.

In summary, broadband created additional revenue between $964 million and $1.2 billion in 2003. That accounts for both new revenue and cannibalized revenue from former dial-up users and retired second phone lines.

TABLE 4. New revenue created by broadband each year (millions of dollars)

Year	Total	1999	2000	2001	2002	2003	2004	2005	2006
Baseline high price[a]	10,595.4	226.9	536.4	1,548	737.4	1,233.4	1,986.3	3005	1,322
Baseline low price[b]	8,337.4	181.4	429.1	1,238.4	577.6	966.1	1,555.8	2,353.6	1,035.4
Aggressive conversion[c]	8,326.5	226.9	536.4	1,548	535.4	895.6	1,442.3	2,182	959.9
Not aggressive[d]	11,410.5	269.8	724.5	2,132.1	737.4	1,233.4	1,986.3	3005	1322

Source: Authors' calculations. See Appendix.
[a]Baseline high price: Broadband Price = $40; 100% are converts 1999-01; 81% converts 2003-06.
[b]Baseline low price: Broadband Price = $36; 100% are converts 1999-01; 81% converts 2003-06.
[c]Aggressive conversion: Broadband Price = $40; 100% are converts 1999-06.
[d]Not aggressive conversion: Broadband Price = $40; 81% converts 1999-06.

We conduct similar calculations for each year, 1999–2006, which we provide in the Appendix and summarize in Table 4. The aggregate revenue gain for 1999–2006 stemming from broadband adoption is $10.6 billion in our baseline specification when broadband prices are $40. That is 46 percent of an estimated $22.6 billion in GDP at the end of the sample (i.e., 47 million households x 12 months x $40 per month).

We are interested in understanding how different assumptions shape the benchmark. Table 4 shows the results. Specifically, if prices are $36 instead of $40, then the total estimate reaches $8.3 billion (41 percent of $20.3 billion). If all broadband adopters are converts (which is higher than plausible) and prices are $40, then our estimates of revenue gains are $2.3 billion lower than in the baseline case. If 81 percent of adopters are converts every year (which is lower than plausible) and prices are $40, then our estimates are $0.9 billion higher.

In other words, while changes to each of these assumptions move the estimate for the level of created new revenue in each year in the expected direction, none of these alters the general pattern *over time* as more households switch from dial-up to broadband. Under any estimate, the additional revenue from the adoption of broadband is large, somewhere between 40 percent and 50 percent of measured revenue for households.

We can summarize it bluntly: measured revenue is what shows up in GDP, but measured revenue is not an estimate of *additional* revenue. Approximately 40 percent to 50 percent of that measured revenue is new. This means that 60 percent to 50 percent of the measured revenue replaces revenue in dial-up and second lines with revenue in broadband—an amount that is a combination of *business stealing* (when revenue goes from one company to another) or cannibalization.

We redid our simulations with one additional change: we accounted for changes in dial-up's prices in late 2006, after AOL dramatically lowered its prices and competitors followed. The only appreciable effect is that converts no longer save $20 at the end of 2006 (when AOL's prices become zero after September 2006). That reduces the cannibalized revenue from converts by approximately $500 million in 2006.[43] This makes a little difference in that year, but does not change any other inference.

There is one additional way to look at these results, in terms of the total benefits over the eight years from 1999 to 2006, which is not expressed in Table 4. This is one number and here is how we calculate it: The largest gains come from those households who adopt in 1999. In their first year of adoption they generate a $226 million gain (in the baseline estimate with a high price). We assume they receive the same benefit in all subsequent seven years in comparison to the alternative, which is going back to dial-up. The same reasoning holds for the group that adopts the next year in 2000. By this reckoning the total revenue gains over the eight years are 8*226.9 + 7*536.4 + … + 1322 = 36.8 (29.0) billion for high (low) price baseline estimate.

Is that a big number? It depends on the point of comparison. It is 36 percent (29 percent) of the size of the total revenue ($100 billion) generated by dial-up over the same time period (adding revenue from 1999 to 2006 from Table 2). The majority of it comes from the latter part of the sample when there is more adoption.

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[43] We get that figure by assuming that AOL has 13.1 million households in 2006, which is a 38 percent decline from the prior year, when the level was 19.5 million households. Those 6.4 million households faced an opportunity cost of $20 a month for eight months of 2006 instead of twelve, which reduces the opportunity cost close to $500 million. Our data on AOL come from Alex Goldman's market share rankings, at http://www.isp-planet.com/research/rankings/usa_h.html.

V.ii. Reinterpreting Incentives for Build-out

These calculations inform the understanding of economic incentives to perform upgrades and provide new insight into a debate about the role of regulatory policy. Other research has noticed that cable companies were the dominant supplier of broadband at the beginning of the diffusion of broadband, but local telephone companies had a slightly higher market share than cable companies by 2006.[44] Hazlett and Caliskan (2008), for example, build an analysis that argues the timing of the switch in market share is consistent with changes in regulatory rules. We show that the cost structure mattered a great deal, and many aspects of this did not depend on regulatory rules at all, but were a combination of the identity of the provider, the density of the location, and technical change (i.e., decreasing costs of build-out). Regulation may have played a role, but we can circumscribe the understanding of what role it played.

Our estimates suggest costs played a central role in these events. The costs of provisioning broadband varied by setting (e.g., density) and time period (e.g., declining over time). Most estimates from the early millennium put the cost of initial upgrading of lines to cable and DSL at $400 to $500 per household in most urban settings, with slightly higher estimates for suburban settings (e.g., an additional $100 dollars) and much higher estimates for rural settings (e.g., another $500 to $1000 per household or more). In all cases, these cost estimates decline to the industry rule-of-thumb for per-household upgrade costs—as little as $250 (for cable) and $150 (for basic DSL) for residences in

[44] This is one place where the data from Pew and the FCC do not entirely agree. Table 1 (from the FCC) gives high market share to cable in the most recent years (2005 and 2006) while Table 3 (from NTIA and Pew) does not. They generally agree in prior years. If the FCC's data are correct, then the statement in the text is not correct, and cable firms have done much better in recent times than telephone firms.

dense urban settings in most recent times.[45] In most cases, post-adoption maintenance costs are estimated to be low, at just more than $100 per household per year.[46]

What do those costs mean? Consider the following illustration for a cable firm that does not experience any cannibalization. Let's say the firm upgrades its system for 2,500 homes and expects only 20 percent of them to take up the service. A cost of $250 per household results in new revenues (at $480 a year) in Internet service. By themselves, this will cover the cost of the upgrade in three years.[47] Additional revenue through (VoIP) telephone service could result in covering those costs sooner. Higher take-up rates also resulted in covering costs sooner. Earlier in the period those costs were higher, so costs were covered later. A similar calculation holds for DSL.[48] In other words, for most providers, the private incentives to upgrade were sufficient to motivate investing in upgrading most urban and suburban areas, and would not have been sufficient only if

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[45] David Burstein, editor of DSL Prime, private communications, September 2008. See also Crandall (2005) for a range of estimates from a variety of sources. In a cable setting this assumes the HFC network has already been built out to support two-way access. Following OECD (2007), Chapter 5, in the case of DSL, this assumes the main cost elements are: customer premises equipment (modem); local loop (access/operational fee for the copper twisted pair); digital subscriber line access multiplexer (DSLAM); aggregation network (L2 switch); broadband remote access server (BAS); and a management system. For a closely related set of estimates, see http://www.ictregulationtoolkit.org/en/PracticeNote.aspx?id=2899. For more recent estimates, see Elixmann et al.'s 2008 WIK Consult Report.

[46] Note what these assumptions imply for a static definition of producer surplus using yearly variable costs. At $480 dollars per year in revenue and $100 in yearly cost, the variable profits per household are $380. With 47 million households in 2006, that leads to $17.8 billion. That static view seems less relevant to us than a definition that incorporates the cost of initial retrofit to enable cable modem service or DSL service, which is the spirit of the discussion below.

[47] Because only 20 percent adopt, the cost per adopting household would be $1,250. In three years the maintenance expense is $300, which means variable revenue is approximately $1,160 on a $40/month contract. Thus, the costs of upgrade are covered approximately after three years. Of course, this does not count the interest costs of borrowing, which would increase costs as well.

[48] The calculation is more plausible with cable firms than telephone firms for reasons alluded to in the text, because national broadband policy for cable investment did not appreciably change over this period. Hence, it is possible to examine investment and its consequences in a constant regulatory policy environment. In contrast, the changes in telephone broadband investment were complex over this time period, so providing a firm date for their change is difficult because it involves both regulatory actors and court decisions in a long interplay. For overview of changes to regulatory policy, see Goldstein (2005), Neuchterlein and Weiser (2005), and for a focus on Internet access see Greenstein (2008).

regulatory rules severely reduced revenue. Similarly, take-up rates would need to be extraordinarily high to justify even a monopoly build-out in most rural areas.[49]

Table 4 leads to a reinterpretation of one common occurrence in recent communications industry lobbying: cable firms have crowed in public forums about the industry's willingness to invest in the last decade, as represented by their aggregate capital expenditure. The industry's total capital expenditures between 1999 and 2005 amounted to $87.1 billion, never dropping below $10 billion in any given year. Some of this covered the costs replacing depreciated capital, to be sure. Yet the acceleration in expenditure after 1998 (from $5 to $10 billion or more annually) is consistent with expenditure aimed to convert cable systems to a digital delivery of cable services,[50] as well as facilitate additional services, such as telephone and Internet access.[51]

We agree with Hazlett and Caliskan (2008) that telephone companies faced regulatory uncertainty in the earlier part of this sample period over the treatment of their investments, and we agree that this can explain why telephone companies reacted to the market opportunity in broadband less aggressively than cable companies.[52] However, our

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[49] For example, consider a cable firm that does not face any cannibalization issues. Even with a 50 percent take up rate, the economics are not favorable for a $40 service for a rural community of 500 homes with $1,500 per household upgrade costs and $100 per household maintenance costs. Without considering borrowing costs, investment costs are not covered until after eight years of revenue. For a local rural telephone firm facing cannibalization issues and a similar cost structure for DSL, the upgrade may be technically infeasible (due to length of lines), as well as simply cost-prohibitive.

[50] The number of digital households increased from 12.2 million households in 2001 to 30.4 in 2006. See http://www.ncta.com/Statistic/Statistic/DigitalCableCustomers.aspx.

[51] The number of households with voice service from cable firms grew from 1.5 million in 2001 to 7.5 at the outset of 2006. The growth has accelerated thereafter, reaching 15.1 at the end of 2007. See http://www.ncta.com/Statistic/Statistic/ResidentialTelephonyCustomers.aspx.

[52] The evidence for this statement is partially evident in Table 1, which shows the growth of household lines. Over this period, cable reached levels of adopters typically two years sooner than similar levels by telephone firms. It is only partially evident in Table 2, which shows revenue growth, because this includes both household and business growth. Cable firms, however, get very little of their revenue from business customers, while telephone companies get a much higher fraction. For example, comparing FCC

analysis adds several additional explanations. Cable did not cannibalize any existing revenue stream, such as from second telephone lines or an existing dial-up ISP (e.g., Ameritech.com). Even without regulatory uncertainty, the incentives at cable firms (revenue per new adopter) were inherently higher, and under any economic investment model that should induce faster deployment. That is, in territories where the two types of firms overlapped, cable companies should have been willing to address costly areas that telephone companies were unwilling to address. In either case, the only big revenue losers were dial-up ISPs, from whom all the business stealing took place. In some cases, this also was a telephone company, and that cannibalization concern also would have reduced net gains to telephone firms.

To summarize, the proper benchmark for calculating such returns was the incremental gains in revenue to those parties from incremental investment aimed at that market. Several factors played a role in calculating incremental gains, such as the identity of the producer, the size of potential business stealing and cannibalization, and the speed of household willingness to respond to new options. Looking at it this way, it should come as no surprise that private firms invested large sums of money when the *additional* gains from doing so were potentially large, as they were for cable firms facing no cannibalization issues over all this time period, and as they were for both cable firms and

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statistics on broadband diffusion to all users with those for residential users for January 2006 suggests that less than 3 percent of the cable lines go to business customers (0.8 out of 29.1 million), while business generates a much higher fraction of telephone company revenue: just more than 10 percent of ADSL lines (2.4 out of 22.5 million) and 35 percent of fiber lines (244,000 out of 685,000). See Tables 1 and 3 in the reports for high-speed services for Internet access, available at http://www.fcc.gov/wcb/iatd/comp.html. Hence, Table 2 also suggests that cable modem access grew sooner than DSL.

telephone firms that faced low upgrade costs in urban and suburban settings later in this time period.

V.iii. Creation of Consumer Surplus

In most studies, estimates of broadband demand indicate that there is substitution between different forms of broadband—that is, substitution between cable and DSL—but only weak substitution between dial-up and broadband. The latter places some constraint on demand for broadband, but not much. There also is evidence of upgrade behavior, with broadband constraining dial-up demand, but not vice-versa.[53] Estimates of broadband demand generally find that it is elastic, though U.S. estimates tend to be lower than those of households in other countries.[54]

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[53] For example, Rappoport, Kridel, Dunnt-Deno, and Alleman (2003) find that broadband service is partially a substitute for dial-up, with cross-price elasticities of .7 among those with dial-up service, while dial-up does not act as a substitute for those with broadband (cross-price elasticity of .02). The cross-price elasticities between cable and DLS are in the .6 and .7 range. Flamm and Chadhuri (2007) use the 2002 Pew Survey and try imputing fewer prices than Rappoport et al. They find that demand for broadband is comparatively more insensitive to prices and their detailed data show that demographic factors shape demand quite a bit. Cardona et al. (2008) find qualitatively similar results to Rappoport et al., with cross-price elasticities between broadband and narrow band of no greater than .5, and that only when these are the only two options. Often their estimates are smaller.

[54] For example, Rappoport et al. (2003) report an own-price elasticity of -1.46 for DSL for a nested logit model applied to a sample of U.S. households in 2000, while Crandall, Sidak, and Singer (2002) find an own-price elasticity of -1.184 for a slightly different sample in a similar time period. Using the same sample, Rappoport, Taylor, and Kridel (2003), page 82, estimate elasticities for different price levels, finding evidence of more elastic demand. The estimates range from an elasticity of close to 1 for DSL and cable modem prices close to $20 a month, and they change in the expected direction. For $30 DSL prices they estimate a price elasticity of -2.1, and for cable modem prices of $40 they estimate -2.35. Estimates on samples of households in other countries tend to find more elastic demand. For example, Pereira and Ribeiro (2006) find an own-price elasticity for broadband (cable and DSL) of -2.84 for a sample of households in Portugal. In a sample of Austrian households Cardona et al. (2007) find similar elasticities for broadband (approximately -2.5) in areas where there are many options, and more inelastic demand (approx -0.97) when DSL is the only broadband option and dial-up provides the only competition to DSL.

For our estimates of consumer surplus we rely on one set of estimates from Savage and Waldman (2004). This study is representative of the type of findings seen in other studies, but easier to use in this context. These authors conducted an extensive survey of dial-up and broadband users in 2002. We prefer this study because it is based on slightly later data, and also because it included both users and nonusers. In addition, the authors used this survey to directly estimate “willingness to pay” measures for attributes of dial-up and broadband service, which facilitates some simple accounting of the value of broadband in comparison to dial-up for existing dial-up users. This is sufficient for illustrations below.[55]

Savage and Waldman’s estimates of the willingness to pay for broadband are net of benefits users receive from dial-up. To remain consistent with their model, we assume users adopt broadband if the additional benefit exceeds the additional cost of converting. The conversion cost sums 1) the increase in subscription fees and 2) the net savings in expense for a second line. If the price of broadband is $36, then the average increase in subscription fee is $16 ($36 less $20). Additionally, many converts dropped a second phone line, saving, on average, $20 per month. This impact affects the “average” consumer surplus of converts differently each year, depending on the average drop rate.

For example, Savage and Waldman’s lowest estimate of the average willingness-to-pay (WTP) for broadband’s speed is around $11 per month, and their highest is around

[55] To be clear, this choice comes with one drawback. It does not fully account for heterogeneity in household willingness-to-pay. It averages out such differences. We do not believe such accounting would alter our benchmark calculations much, but we acknowledge it is an open question. The study of Rappoport, Taylor, and Kridel (2003) takes steps in that direction, but did not provide sufficient information to make a full estimate (such as the distribution of dial-up among this population and its correspondence to WTP for broadband, or standard errors on their estimates of heterogeneous demand).

$22 for the most experienced and educated user. They also find that users pay more for broadband because it is more reliable and always on—between $1 and $18 more, depending on how much more reliability the user perceives in broadband. Savage and Waldman assume that dial-up has half the reliability of broadband, yielding an additional value of $9 on average. [56]

Savage and Waldman provide an estimate for the number of users who switched from dial-up, but not one for new Internet users. New adopters started becoming more frequent after the 2002 survey used by Savage and Waldman. Even though some of the new adopters (surely) had experience with the Internet (e.g., as students or at work), we take a conservative approach to estimating surplus for nonconverts. We assume their willingness to pay is what they paid (i.e., they received no consumer surplus). This is consistent with our focus on generating a conservative estimate of the substitution bias arising solely from upgrade behavior among previous dial-up users.[57]

In our base specification, if the subscription fees for broadband are $40 a month, and someone converts from a $20 a month dial-up account, then the conversion cost is $20, and we call that the *maximum conversion cost*. For those who paid the maximum

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[56] It is reassuring that the average in the Savage and Waldman study, which examines a sample of only previous dial-up users, is in the same range as the estimates for (WTP) from Rappoport, Taylor, and Kridel (2003), which examines a sample of all households. In the latter case the average WTP in their entire sample is $36.8 for cable and $32 for DSL. Among a truncated sample of likely adopters— those with WTP for broadband above $40—the average WTP is $53.45 for cable and $52.05 for DSL. Note: to make these estimates into a WTP for a conversation from dial-up to broadband, one would then need information about (or make assumptions about) the distribution of former dial-up users in this sample and, among that sub-sample, make further assumptions about their use of second telephone lines.

[57] This is one place where Savage and Waldman's estimates are much easier to use than the estimates of Rappoport, Taylor, and Kridel. Though the latter provide a skewed distribution of WTP, they give no other indication about how these estimates compare against observable features of the data, such as whether households had prior experience with dial-up Internet.

conversion cost, the low end of the estimates of willingness-to-pay is just enough to cover the additional cost.

To be clear, we do not use this model to predict which household did and did not adopt broadband, as Savage and Waldman did. Rather, we assume that the quantity demanded must result in the number of adopting households, as in Table 3. Then we calculate the level of consumer surplus consistent with Savage and Waldman's estimates, while varying assumptions about prices and conversions.

A full accounting of this surplus can be found in the Appendix. It varies from \$6/\$10 per month on average in 1999–2001 (when the price is \$40/\$36 and we assume that no household drops its second phone line), to \$11.35/\$15.35 per month after 2002 (when we assume that all converts dropped their second line).

TABLE 5 Consumer surplus in millions of dollars (as a fraction of sum of consumer surplus plus revenue)

Year	Total	999	000	001	002	003	004	005	006
Baseline high price[a]	(31.2%) 4,818.7	68	160.9	464.4	367.2	614.2	989.2	1,496.5	658.3
Baseline low price[b]	(44.4%) 6,735.7	113.4	268.2	774	496.7	830.9	1337.9	2024.1	890.5
Aggressive conversion[c]	(43.2%) 6,349.7	68	160.9	464.4	503.5	842.1	1356.3	2051.8	902.7
Not aggressive[d]	(30.0%) 4,687.9	55.1	130.3	376.1	367.2	614.2	989.2	1496.5	658.3

Source: Authors' calculations. See Appendix.

[a]Baseline high price: Broadband Price = \$40; 100% are converts 1999-01; 81% converts 2003-06.
[b]Baseline low price: Broadband Price = \$36; 100% are converts 1999-01; 81% converts 2003-06.
[c]Aggressive conversion: Broadband Price = \$40; 100% are converts 1999-06.
[d]Not aggressive conversion: Broadband Price = \$40; 81% converts 1999-06.

Table 5 provides a summary of these results. The approximately 40 million households that converted to broadband since the beginning of the dial-up market received an additional benefit from their conversion that amounts to somewhere between $4.7 billion and $6.7 billion in 2006.

Comparing Tables 4 and 5 also shows how different assumptions shape estimates of the distribution of gains from innovation. In the two baseline cases, the total gains from the diffusion of broadband reach just over $15 billion, though they differ in the distribution of return.[58] As expected, higher prices lead to lower consumer surplus as a fraction of new value generated, that is, 31.2 percent and 44.4 percent for broadband prices equal to $40 and $36, respectively.

Comparing two assumptions—that 100 percent of broadband users upgraded from dial-up (an aggressive conversion, which is too high) versus 81 percent of them (an unaggressive conversion, which is too low)—alters total surplus only a little, but it does alter estimates of the distribution of returns. Aggressive conversion reduces total surplus by $0.8 billion (compared to the baseline), while unaggressive conversion increases it by $0.6 billion. Nevertheless, these assumptions provide a very different distribution of gains from innovation: 43.2 percent and 30.0 percent, respectively. In comparison to the baseline simulation, assuming an aggressive conversion of dial-up users to broadband

[58] In the $40 baseline estimate, the total gains are 4,818.7 + 10,595.4 = 15,414.1. In the $36 baseline estimate the total gains are 6,735.7 + 8,337.4 = $15,073.1. When only 81 percent of the broadband adopters has upgraded from dial-up, then a reduction in price reduces new producer surplus each year, but increases consumers surplus by only 81 percent of the new revenue for vendors. The 19 percent consumer surplus is lost to our assumption that new Internet users generate no consumer surplus. The estimates for total surplus are not the same under different prices except under the assumption that all broadband users are converts from dial-up. Accordingly, in the simulation at $40 (and $36) with aggressive conversion, the total is 6,349.7 + 8,326.5 = $14,676.2. At $40 without aggressive conversion, the total is 4,687.9 + 11,410.5 = $16,098.4.

yields a large gain for consumer surplus and a commensurate loss for producer surplus. Assuming an unaggressive conversion has just the opposite effect.

Plainly stated, the information in Table 4 gives a sense of the range of changes that come about from changes in the assumptions, but the direction of change is not surprising. Rather, these estimates place limits on the range of the benchmark for consumer surplus. Consumer surplus is between 31.2 percent and 44.4 percent of the new revenue generated, and this is entirely an unmeasured gain from the diffusion of broadband.

Once again, there is one additional way to look at these results, in terms of the total benefits over the eight years from 1999 to 2006, which Table 5 does not express. This is one number, which we calculate here. The largest consumer surplus accrues to those households who adopt in 1999. In their first year of adoption they receive a $68 million gain (in the baseline estimate with a high price), and then we assume they receive the same amount in all subsequent seven years. By this reckoning the total revenue gains over the eight years are 8*68 + 7*160.9 + … + 658 = 15.4 (22.2) billion for high (low) price baseline estimate.

Is this a large number? By comparison with the size of the total new revenue, which is $36 billion ($29 billion), the gains to consumers generated by broadband over the same time period is 42 percent (76 percent) of the size of total new revenue gains. Notice, too, in either simulation new consumer surplus plus new revenue add up to approximately $51 billion, so prices simply determine the distribution of gains.

Once again, we stress that these are benchmark estimates. First, other researchers found considerable heterogeneity in the demand for broadband, with some adopters of broadband willing to pay far above the market price. The Savage-Waldman estimate also measures some of this inelastic demand, but it truncates the level of that valuation among the biggest fanatics. We have not counted this highly inelastic demand in our valuation.

Second, we have made no adjustment to these estimates to account for the change in dial-up pricing, particularly AOL's. While we are comfortable with this lack of adjustment—especially considering how AOL's price change shapes our estimates—adoption is a slow process; and the price decline came too late in 2006 to have an effect on broadband adoption. It almost goes without saying, but nobody expects that most broadband users would switch back to dial-up even if some dial-up became free.

Third, survey research tends to find a larger willingness to pay from users who are paying not to have something taken away after they have experienced it than those who are paying for something they have yet to experience. Savage and Waldman corrected for this effect by asking both users and nonusers about their valuations; however, the survey was conducted before widespread broadband adoption, so the answers about value would most likely be higher if the survey were conducted today among actual users.

Indeed, more recent estimates by Rosston, Savage, and Waldman (2010) are done with a sample from seven years later, and get slightly higher willingness to pay, but in the same ballpark as Savage and Waldman (2004). This gives us further confidence that these older surveys are robust.

V.iv. An Adjusted Price Index

Standard economic reasoning suggests that the price index will be mismeasured when a new good results in large consumer surplus. That must be true in this example, too. We briefly walk through the mechanics just to (1) verify that intuition, (2) provide a range for the estimates, (3) decompose the causes, and (4) compare against the CPI.

The standard recommendation is to use the adopters' reservation value for the new good; that is, the price index should use the maximum of what a user would have been willing to expend to get the new good prior to adopting the new good. Thus, the starting point is straightforward. Converts were willing to pay a virtual price of $51.35 per month on average, but had to pay less. For converts, this was equivalent to a decline in price of $11.35 ($15.35), but none of this was measured. In other words, against a $40 ($36) price for broadband, an average of $11.35 ($15.35) consumer surplus is equivalent to 22 percent (30 percent) of the monthly price paid by converts for service.

We now ask how far a price index would have to fall in order to capture the gains that converts experienced. Table 6 illustrates this result, calculating a weighted average of the price change for each year as if only converts experienced a price decline. Weights fall into four categories: (1) dial-up users, (2) existing broadband users, (3) new broadband users who are new Internet users, and (4) broadband users making an upgrade this year. In the baseline specification, converts to broadband (who do not retire a second line, by construction) experience a 13 percent decline in price (from $46 to $40) from 1999 to 2001, which we represent as 0.87. Converts from 2002 to 2006 (who do retire a second line, by construction) experience a 22 percent decline in price (from $51.35 to

$40), which we represent as 0.78. We assume all others experience no price decline, which we represent as 1.0.

Table 6 shows that this exercise results in an average price decline between 0.984 and 0.978, because in most years only a small percentage of households with Internet access upgraded to broadband. That means the price index for all Internet access should decline between 1.6 percent and 2.2 percent a year by 2006. In this exercise the correction is largest in the most recent years, when there are more upgrades as a percentage of all Internet households.

TABLE 6 Weighted average of price decline.

Year	999	2000	001	002	003	004	005	006	Average
Baseline high price[a]	99.6	99.3	98.4	98.9	98.3	97.5	96.6	98.7	98.4
Baseline low price[b]	99.4	98.9	97.3	98.5	97.7	96.7	95.5	98.3	97.8
Aggressive conversion[c]	99.6	99.3	98.4	98.7	97.9	96.7	96.0	98.2	98.1
Not aggressive[d]	99.7	99.4	98.7	98.9	98.3	97.5	96.6	98.8	98.5

Source: Authors' calculations.

[a]Baseline high price: Broadband Price = $40; 100% are converts 1999-01; 81% converts 2003-06.
[b]Baseline low price: Broadband Price = $36; 100% are converts 1999-01; 81% converts 2003-06.
[c]Aggressive conversion: Broadband Price = $40; 100% are converts 1999-06.
[d]Not aggressive conversion: Broadband Price = $40; 81% converts 1999-06.

Another way to represent the price decline is through a Paasche and Laspeyeres index over eight years—that is, using either the populations in 1999 and 2006 as the baseline. The baseline matters because there was so much change in the characteristics of this population over these eight years (Table 3). In 2006, there were 47 million broadband users and 34.7 million dial-up users. Hence, the 2006 Paasche and Laspeyeres indices will use different base populations because of (1) the entry of new Internet users who later convert to broadband, (2) the entry of new Internet users who use dial-up in 2006, and (3) the entry of new users who go straight to broadband.

The different base years matter. If the population in 2006 serves as the baseline, then 48.9 percent (39.1/81.7) of households adopted broadband after converting from dial-up in the baseline estimates. In the baseline estimates, 24.5 percent (9.6/39.1) of households experienced a 13 percent price decline in 1999–2001 and 59.8 percent (23.4/39.1) experienced a 22 percent price decline from 2002–2006.[59] Over eight years that adds up to an 8.0 percent decline in the Internet access price index, even with high broadband prices (i.e., $40). It is an 11.2 percent decline in prices with lower broadband prices (i.e., $36). In contrast, if the 1999 population serves as the baseline, then it is plausible that all of the users converted to broadband by 2006.[60] We assume adoption behavior consistent with our baseline model. That is, 9.6 million households experienced a 13 percent (21 percent) price decline between 1999 and 2001 if broadband prices are $40 ($36). We assume the remainder (34.7 – 0.9 – 9.6 = 24.2) upgraded between 2002–2006, and that translates into a 22 percent ($30) price decline. Accordingly, when

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[59] It is plausible because we have 47 million broadband adopters by 2006. We began with 0.9 million in 1999 and 7 million are new Internet users between 2002 and 2006 by construction. Of the remainder, 9.6 million convert from dial-up to broadband between 1999 and 2001. Hence, if all households converted, then 23.4 million households converted between 2002 and 2006. This is well below 39.5 (47 - 7 - 9.6 - 0.9). See Appendix.

[60] This seems natural to us since because it does not come close to the total 39.1 million broadband converts between 1999 and 2006.

broadband prices are \$40 (\$36), this population experiences an 18.4 percent (27.3 percent) price decline.[61]

The Paasche and Laspeyeres index groups the estimates in Table 6. The minimum is 8.0 percent (11.2 percent) and the maximum is 18.4 percent (27.4 percent), or an average of 1.0 percent (1.4 percent), and 2.1 percent (3.4 percent) decline per year. Our baseline results are 1.6 percent (2.2 percent), just between the minimum and maximum.[62] More importantly, there is a big difference in the *timing* of the recorded price decline. Accounting for the upgrade *when users upgraded* would have realized a large fraction of the benefits at an early moment.

That simulation informs the puzzling inconsistency between widespread adoption of broadband, as documented in Table 1, and the lack of measured appreciable decline in transactional prices over eight years, as displayed in the CPI for Internet access. A properly measured broadband price index shows a large change in prices, resolving this apparent puzzle. If the pricing concentrates on a population of households that were early adopters of the Internet, then the unmeasured price decline is quite large.

We now decompose the underlying cause of these conclusions by asking: how much price decline arises from the retirement of second phone lines? As it turns out, second lines are not as important as new surplus from conversion. For example, in our

[61] Using the 2006 broadband population as the baseline, we can estimate a price index that leaves out dial-up users, but is averaged over a different base. In the baseline estimate when prices are \$40 (\$36) we find that 20.8 percent (9.6/46.1) of upgrading households experienced an average of a 13 percent (21 percent) price decline from 1999–2001 and 63.9 percent (29.5/46.1) experienced a 22 percent (30 percent) price decline from 2002–2006, while 15.1 percent (7/46.1) experienced no price decline. That yields a 16.7 percent (23.4 percent) price decline over all eight years for upgrading households. Including all broadband users (i.e., adding the 0.9 million adopters prior to 1999) yields 16.3 percent and 22.9 percent, respectively.

[62] The comparison in the text is over the entire population of households, and each household experiences only one upgrade, by construction. Hence, to make them comparable it is appropriate to look at the average rate of decline per year.

baseline estimates for $40 broadband, the gain is $11.35. The dropped second phone line is responsible for $5.35, while the consumer surplus is responsible for $6. When the baseline price is $36, then consumer surplus is comparatively more important. The second line is still responsible for $5.35, but consumer surplus is now responsible for $10. These expenses only shape decision making during 2002–2006 in the baseline estimates. In other words, removing the savings on the second line from the price index would remove anywhere from 30 percent to 40 percent of the total savings in 2002–2006, or 21 percent to 28 percent of the savings for 1999–2006.

BLS price indices do not normally count the savings of expenditure in one category (on a second telephone line) as an input into calculating the price index for another (Internet access). We appreciate this procedural norm, but we are not fully sympathetic due to the misunderstanding it produces for policy. Accounting should take place somewhere, and if not, the absence of such accounting should be acknowledged so policy users of the price indices can properly interpret what they observe.

VI. Conclusion

Prior research of broadband's effect on the U.S. economy mismeasures its true economic impact. This is the first study to provide estimates consistent with actual broadband diffusion. We conclude that prior research was dangerously misleading at best, and rendered with flawed economic reasoning and incorrect statistical approaches. These reports did not employ the best available sources of data about the diffusion of broadband, did not attempt to calibrate their conclusions against all available data, and did not provide economically plausible forecasts about the range of economic gains from broadband.

While broadband accounted for $28 billion of the GDP in 2006, approximately $20 to $22 billion was associated with household use in 2006. Of that amount, we showed that approximately $8.3 and $10.6 billion of it was additional revenue (above and beyond what dial-up would have generated), and between $6.7 and $4.8 billion was consumer surplus. That is, broadband generated new additional revenue between 40 percent and 50 percent of measured GDP, while consumer surplus (which was not measured) was between 31 percent and 47 percent of the newly created revenue. The upgrade was equivalent to an unmeasured decline in price of between 1.6 percent and 2.2 percent per year in all Internet access prices.

The study has focused on measuring the factors that shaped the anticipated incremental costs and benefits from the national upgrade to broadband. More accurate measurement illustrates why policy oriented towards relying on private investment succeeded as it did: the incremental returns were sufficiently large enough to generate large investments by broadband providers, especially cable firms. This explanation differs from hypotheses that stress the role of regulatory change.

We also conclude that the commonly used government statistics, such as a BLS price index, did not measure the full gains to broadband adopters. It would have to record a decline in price to account for the gains from merely upgrading from dial-up to broadband.

Our estimates suggest that much of the debate about universal service policy is based on correct assumptions that there are low private economic incentives for build-out in low-density (e.g., high-cost) environments. Moreover, the same economic logic also suggests that non-private economic gains from such deployment would have to be substantial to justify large subsidies. It is an open question whether these economic gains are large enough by themselves to justify a national program beyond what is already done in the Stimulus Bill and other universal service programs. We are skeptical that many high-cost areas would pass such a social cost/benefit economic benchmark. Related, this is an interpretation for why the National Broadband Plan stresses the social reasons for national subsidies (e.g., fostering public health, better education, civic communication) rather than economic reasons (e.g., local growth, employment).

We do not want to leave the impression that this study settles measurement questions, as many other issues related to quality adjustments still remain unsettled. Because these are difficult to measure, they will likely prove difficult to address. As a brief example, many broadband firms have recently upgraded the bandwidth of their lines without increasing prices for consumers; such upgrades are difficult to record and measure. In addition, the Internet access price index does not adjust for the improvement in the quality of the many free complements that have become available over this time period, such as improvements in the Google search engine, Yahoo! portal, MSN instant messaging client, or caching by Akamai. These investments increase the quality of the Internet experience for users.

In addition, our estimates did not include an analysis of the benefits versus costs not considered by parties involved in the transaction. In the body of the text we included a range of examples that might incrementally shape the experience of other suppliers. However, unlike prior literature, we have tried not to allow the presence of externalities in broadband economics to become a license to inflate the gains from the deployment of broadband, and we await further work on this topic.

We do not, therefore, view our own attempts here as the final word on the estimation of the size of these effects; rather, we view them as an attempt to benchmark the size of the issues in one specific case, and by showing their scale, motivate others to undertake related exercises with greater care than previously shown.

References

Atkinson, R. D., S. J. Ezell, S. M. Andes, D. D. Castro, and R. Bennett. 2010. The Internet economy 25 years after .com. The Information Technology and Innovation Foundation. March. http://www.itif.org/.

Boskin, M., E. Dulberger, R. Gordon, Z. Griliches, and D. Jorgenson. 1996. The Boskin commission report: Toward a more accurate measure of the cost of living. http://www.ssa.gov/history/reports/boskinrpt.html.

Braithwait, S. 1980. The substitution bias of the Laspeyeres Price Index: Analysis using estimated cost of living indexes. *American Economic Review* 70 (1): 64–77.

Bresnahan, T. F., and R. J. Gordon. 1997. *The economics of new goods.* Chicago: University of Chicago Press.

Cardona, M., A. Schwarz, B. B. Yurtoglu, and C. Zulehner. 2008. Demand estimation and market definition for broadband Internet services. Mimeo. University of Vienna.

Chen, Y., and S. Savage. 2007. The effects of competition on the price for cable modem Internet access. NET Institute WP No. 07-13. http://ssrn.com/abstract=1021333.

Connected Nation. 2008. "The Economic Impact of Stimulating Broadband Nationally." Mimeo. http://www.connectednation.com/_documents/Connected_Nation_EIS_Study_Full_Report_02212008.pdf

Crandall, R. 2005. Broadband communications. In *Handbook of telecommunications economics,* ed. Martin Cave, Sumit Majumdar, and Ingo Vogelsang, 156-187. Amsterdam, The Netherlands: Elsevier.

——— and C. Jackson. 2003. The 500 billion dollar opportunity: The potential economic benefit of widespread diffusion of broadband access. In *Down to the wire: Studies in the diffusion and regulation of telecommunications technologies*, ed. Allan L. Shampine. Hauppauge, NJ: Nova Science Publishers.

———, W., J. G. Sidak, and H. J. Singer. 2002. The empirical case against asymmetric regulation of broadband Internet access. *Berkeley Law and Technology Journal* 17 (1): 953–87.

Downes, T., and S. Greenstein. 2002. Universal access and local Internet markets in the United States. *Research Policy* 31(7): 1035–52.

Duffy-Deno, K. 2001. Demand for additional lines: An empirical note. *Information Economics and Policy* 13 (3): 283–99.

Eisner, J., and T. Waldon. 2001. The demand for bandwidth: Second telephone lines and on-line services. *Information Economics and Policy* 13(3): 301–9.

D. Elixmann, D. Ilic, K-H. Neumann, and T. Plückebaum. 2008. *The economics of next generation access—Study for the European competitive telecommunications association.* Bad Honnef, Germany: WIK Consult. http://www.wik.org/content_e/ecta/ECTA%20NGA_masterfile_2008_09_15_V1.pdf.

Federal Communications Commission. 2007. *Trends in telephone service.* http://www.fcc.gov/wcb/iatd/trends.html.

Flamm, K., and A. Chadhuri. 2007. An analysis of the determinants of broadband access. *Telecommunications Policy* 31(6/7): 312–26.

Flamm, K., A. Friedlander, J. Horrigan, and W. Lehr. 2007. Measuring broadband: Improving communications policy making through better data collection. Washington, DC: Pew Internet and American Life Project, November. http://www.pewinternet.org/pdfs/PIP_Measuring%20Broadband.pdf.

Fogel, R. 1962. A quantitative approach to the study of railroads in American economic growth. *Journal of Economic History* 22:162–97.

Goldfarb, A. 2004. Concentration in advertising-supported online markets: An empirical approach. *Economics of Innovation and New Technology* 13(6): 581–94.

Goldstein, Fred R. 2005. *The great telecom meltdown.* Norwood, MA: Artech House.

Greenstein, S. 2008. The evolution of market structure for Internet access in the United States. In *The commercialization of the Internet and its impact on American business*, ed. William Aspray and Paul Ceruzzi, 47–104. Cambridge, MA: MIT Press.

Griliches, Zvi, and Iain Cockburn. 1994. Generics and new goods in pharmaceutical price indexes. *American Economic Review* 84(5): 1213-1232.

Hamilton Consultants, Inc. 2009. Economic value of the advertising supported Internet ecosystem. http://www.iab.net/economicvalue.

Hausman, Jerry. 1997. Valuing the effect of regulation on new services in telecommunications. Brookings Papers on Economic Activity, Micro, 1-54.

Hazlett, Tom, and Anil Caliskan. 2008. *Review of Network Economics* December (7): 460-80.

Hitt, Lorin, and Prasanna Taumbe. 2007. Broadband adoption and content consumption. *Information and Economic Policy*, 19, pp 362-378.

Hong, Seung-Hyun. 2007. The recent growth of the Internet and changes to household level demand for entertainment. *Information and Economic Policy*, 19, pp 304-318.

Horrigan, J. 2007. Home broadband adoption, 2007, June, Washington, D.C.: Pew Internet and American Life Project. http://www.pewinternet.org/.

NTIA (National Telecommunications and Information Administration). 2004. A nation online: Entering the broadband age. http://www.ntia.doc.gov/reports.html.

———. 1995. Falling through the net: A survey of the 'have nots' in rural and urban America. http://www.ntia.doc.gov/reports.html (accessed March 17, 2006).

Nuechterlein, J. E., and P. J. Weiser. 2005. *Digital crossroads: American telecommunications policy in the Internet age.* Cambridge, MA: MIT Press.

Organization for Economic Co-operation and Development (OECD). 2007. OECD Communications Outlook 2007. Paris: OECD.

Pereira, P., and T. Ribeiro. 2006. The impact on broadband access to the Internet of the dual ownership of telephone and cable networks. Mimeo.

Rappoport, P., D. Kridel, L. Taylor, K. Dunny-Deno, and J. Alleman. 2003. Residential demand for access to the Internet. In *International handbook of telecommunications economics*, vol. II, ed. G. Madden, 55-72. Cheltenham, UK: Edward Elgar.

Rappoport, P. L. Taylor, and D. Kridel. 2003. Willingness to pay and demand for broadband services. In *Down to the wire*, ed. Allan L. Shampine. Hauppauge, NJ: Nova Science Publishers Inc.

Reinsdorf, M. 1993. The effect of outlet price differentials on the U.S. Consumer Price Index. In *Price measurements and their users: NBER studies in income and wealth*, vol. 57, ed. M. F. Foss, M. E. Mansur, and A. H. Young, 227–54. Chicago: University of Chicago Press.

Rosston, G. 2009. The rise and fall of third party high-speed access. *Information and Economic Policy* 21 (1): 21-33.

Rosston, G., S. J. Savage, and D. Waldman, 2010. Household demand for broadband Internet service. SIEPR Paper 09-008. http://siepr.stanford.edu/publicationsprofile/2109.

Savage, S. J., and D. Waldman. 2004. United States demand for Internet access. *Review of Network Economics* 3(3): 228-247.

Stranger, G., and S. Greenstein. 2007. Pricing in the shadow of firm turnover: ISPs in the 1990s. *International Journal of Industrial Organization* 26(3): 625–42.

Appendix

Adjustments for Table 2.

Table 2 is constructed from the Annual Service Survey, conducted by the U.S. Census. The Census Service Annual Survey is available for NAICS 51, as archived on http://www.census.gov/econ/www/servmenu.html. The annual surveys differ from the five-year economic censuses. The annual service surveys are estimates of economic activity, not complete censuses of economic activity. They are designed to provide short-run estimation at a greater frequency than every five years.

In general these estimates are based on a particular sampling frame (i.e., data collected from a small group of firms). In rapidly changing industries, such sampling frames can, and do, become outdated quickly. The census alters the sampling frame frequently (as often as every three or four years), but it does not apply new lessons to old data. That is, it does not use a new sampling frame to re-estimate archival data. Hence, historical inconsistencies run throughout this data, particularly in years when new sampling frames are introduced (in this case that occurs between 2000 and 2001, and between 2003 and 2004).

The annual survey does not provide guidance about how to adjust data to make inconsistent historical data consistent with each other. Conversations with employees indicated no plans to correct historical inconsistencies. In all cases, we try to stay as close as possible to data in published reports and to use the latest publication, which sometimes corrects for errors in sampling frame.

We take advantage of a lucky break in 2004. The census published two sets of estimates, one using an old sampling frame and (a few months later) one using the new. This permitted a direct comparison of the two sampling frames and a correction for prior years (i.e., 2001, 2002, and 2003).

Cable modem revenue

For 1998, 1999, and 2000, the original data were taken from the tables for NAICS 5175, from the 2000 report. The data in 2001, 2002, and 2003 came from the listing for NAICS 5175, from the report for 2004, which used a new sampling frame that differed from prior years. The data for 2004, 2005, and 2006 came from NAICS 5175, from the 2005 report, which also used a new sampling frame. Due to a change in the sampling frame, the data from 2004–2006 were no longer consistent with the data from 2001–2003. For 2004, there were estimates using both sampling frames, and the data for the new sampling frame (used in 2004–2006) were found to be 10 percent higher than the old sampling frame (used in 2001–2004). For consistency, data in 2001, 2002, and 2003 were adjusted upward 10 percent.

DSL revenue

The census annual survey did not report DSL revenue as a separate item prior to 2001. The data for 2001, 2002, and 2003 originally came from NAICS 5133 and did not include backbone services. Data for 2004, 2005, and 2006 came from NAICS 5171, from the 2006 report, which used a new sampling frame. As with the other data, due to a change in the sampling frame, the data from 2004–2005 were potentially inconsistent with the data from 2001–2003. For 2004, there were estimates using both sampling frames and the data for the new sampling frame (used in 2004–2006) was found to be inconsistent with the old sampling frame (used in 2001–2004). Data in 2001, 2002, and 2003 were not adjusted by a fixed percentage, because doing so would have led to implausibly high revenue in 2001 and 2002 that would have been inconsistent with FCC and Pew data on the number and growth of deployed DSL lines. To generate a series consistent with 2004 and with the FCC data on deployment, we started with 2004 and worked backwards to data for 1999, 2000, 2001, 2002, and 2003. These have growth rates similar to growth in total DSL lines, as reported by the FCC data on user growth in DSL lines—both business and household users, not just households as reported in Table 1 (though the data were taken from the same source). These replace all reported numbers in 2001, 2002, and 2003; and these replace missing values in 1999 and 2000.

Dial-up revenue

The original data in 1998, 1999, and 2000 were taken from the tables for NAICS 514191, from the 2000 report. The data in 2001, 2002, and 2003 came from the table for NAICS 514191, which used a new sampling frame from prior years. The data for 2004, 2005, and 2006 were for NAICS 5181111, from the 2006 report, which also used a new sampling frame. Due to a change in the sampling frame, the data from 2004–2006 were no longer consistent with the data from 2001–2003. For 2004, there were estimates using both sampling frames. The data for the new sampling frame (used in 2004–2006) were found to be 33 percent higher than the old sampling frame (used in 2001–2004). For consistency, data in 2001, 2002, and 2003 were adjusted upward 33 percent.

Wireless revenue

The data for 2004 and 2005 came from NAICS 517212, from the report for 2005. The report included Internet access services for wireless carriers, but not satellite services. Disclosure issues prevented publication in 2006.

Prior to adjustment for sampling frame inconsistencies, the reports from the census annual survey (for 1998–2000, 2001–2003, 2004–2006) originally appeared as follows:

	1998	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Dial-up revenue	5,499	8,966	12,345	10,339	10,596	10,656	14,081	12,240	10,983
Cable revenue	138	274	903	2,364	3,743	6,702	9,435	11,139	13,156
DSL revenue				4,917	4,343	4,329	11,924	13,561	15,066
Wireless revenue							668	1140	.

Simulations: $36 Cases

Broadband Bonus - Base Case

Year	1999	2000	2001	2002	2003	2004	2005	2006
Assumptions:								
Usage Rates:								
Households	105,000,000	106,000,000	107,000,000	108,000,000	109,000,000	110,000,000	111,000,000	112,000,000
Overall Internet Adoption	33.8%	41.5%	50.3%	52.5%	54.6%	60.0%	66.0%	73.0%
Broadband Adoption	0.9%	3.0%	9.0%	12.0%	17.0%	25.0%	37.0%	42.0%
Dial-up Adoption	32.9%	38.5%	41.3%	40.5%	37.6%	35.0%	29.0%	31.0%
Costs:								
Broadband Cost	$ 36	$ 36	$ 36	$ 36	$ 36	$ 36	$ 36	$ 36
Dial-up Cost	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20
Second Phone Line Cost	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20
Converts:								
% Converts	100%	100%	100%	81%	81%	81%	81%	81%
# Second Lines	23,600,000	26,200,000	26,300,000	18,400,000	16,000,000	13,800,000	12,100,000	10,500,000
Δ in Second Lines		2,600,000	100,000	(7,900,000)	(2,400,000)	(2,200,000)	(1,700,000)	(1,600,000)
% Converts Dropping Second Phone line	0%	0%	0%	33%	33%	33%	33%	33%
Average Convert Saving from Dropped Line	-	-	-	$ 6.60	$ 6.60	$ 6.60	$ 6.60	$ 6.60
Additional Benefit of Broadband	$ 26	$ 26	$ 26	$ 26	$ 26	$ 26	$ 26	$ 26
Calculations:								
Total Household Adopters	35,490,000	43,990,000	53,821,000	56,700,000	59,514,000	66,000,000	73,260,000	81,760,000
Total Broadband Adopters	945,000	3,180,000	9,630,000	12,960,000	18,530,000	27,500,000	41,070,000	47,040,000
Total Dial-up Adopters	34,545,000	40,810,000	44,191,000	43,740,000	40,984,000	38,500,000	32,190,000	34,720,000
New Broadband Users	945,000	2,235,000	6,450,000	3,330,000	5,570,000	8,970,000	13,570,000	5,970,000
New Dial-up to Broadband Converts	945,000	2,235,000	6,450,000	2,697,300	4,511,700	7,265,700	10,991,700	4,835,700
Broadband Adopters (New Internet Users)	-	-	-	632,700	1,058,300	1,704,300	2,578,300	1,134,300
Cumulative Dial-up to Broadband Converts	945,000	3,180,000	9,630,000	12,327,300	16,839,000	24,104,700	35,096,400	39,932,100
Cumulative Broadband Adopters (NIU)	-	-	-	632,700	1,691,000	3,395,300	5,973,600	7,107,900
Annual Broadband Revenue	$ 408,240,000	$ 1,373,760,000	$ 4,160,160,000	$ 5,598,720,000	$ 8,004,960,000	$ 11,880,000,000	$ 17,742,240,000	$ 20,321,280,000
Annual Dial-up Revenue	$ 8,290,800,000	$ 9,794,400,000	$ 10,605,840,000	$ 10,497,600,000	$ 9,836,160,000	$ 9,240,000,000	$ 7,725,600,000	$ 8,332,800,000
Broadband Converts Revenue (Annual Δ)	$ 408,240,000	$ 965,520,000	$ 2,786,400,000	$ 1,165,233,600	$ 1,949,054,400	$ 3,138,782,400	$ 4,748,414,400	$ 2,089,022,400
Broadband Adopters (NIU) Revenue (Annual Δ)	-	-	-	$ 273,326,400	$ 457,185,600	$ 736,257,600	$ 1,113,825,600	$ 490,017,600
Cannibalized Dial-up Revenue	$ 226,800,000	$ 536,400,000	$ 1,548,000,000	$ 647,352,000	$ 1,082,808,000	$ 1,743,768,000	$ 2,638,008,000	$ 1,160,568,000
Retired Second Phone Line Revenue	-	-	-	$ 213,626,160	$ 357,326,640	$ 575,443,440	$ 870,542,640	$ 382,987,440
Total Conversion Cost	$ 226,800,000	$ 536,400,000	$ 1,548,000,000	$ 860,978,160	$ 1,440,134,640	$ 2,319,211,440	$ 3,508,550,640	$ 1,543,555,440
Additional Revenue from Broadband	**$ 181,440,000**	**$ 429,120,000**	**$ 1,238,400,000**	**$ 577,581,840**	**$ 966,105,360**	**$ 1,555,828,560**	**$ 2,353,689,360**	**$ 1,035,484,560**
Avg. Monthly Broadband Benefit for Converts	$ 10.00	$ 10.00	$ 10.00	$ 15.35	$ 15.35	$ 15.35	$ 15.35	$ 15.35
Implied Decline in Price for Converts	28%	28%	28%	43%	43%	43%	43%	43%
Annual Total Broadband Benefit (Converts)	**$ 113,400,000**	**$ 268,200,000**	**$ 774,000,000**	**$ 496,713,190**	**$ 830,838,578**	**$ 1,337,993,186**	**$ 2,024,143,538**	**$ 890,503,826**
Revenue + Consumer Surplus	**$ 294,840,000**	**$ 697,320,000**	**$ 2,012,400,000**	**$ 1,074,295,030**	**$ 1,796,943,938**	**$ 2,893,821,746**	**$ 4,377,832,898**	**$ 1,925,988,386**
Total Gross Benefits for Broadband Since 1999	**$ 294,840,000**	**$ 992,160,000**	**$ 3,004,560,000**	**$ 4,078,855,030**	**$ 5,875,798,968**	**$ 8,769,620,714**	**$ 13,147,453,613**	**$ 15,073,441,999**

Broadband Bonus - Conservative Case

Year	1999	2000	2001	2002	2003	2004	2005	2006
Assumptions:								
Usage Rates:								
Households	105,000,000	106,000,000	107,000,000	108,000,000	109,000,000	110,000,000	111,000,000	112,000,000
Overall Internet Adoption	33.8%	41.5%	50.3%	52.5%	54.6%	60.0%	66.0%	73.0%
Broadband Adoption	0.9%	3.0%	9.0%	12.0%	17.0%	25.0%	37.0%	42.0%
Dial-up Adoption	32.9%	38.5%	41.3%	40.5%	37.6%	35.0%	29.0%	31.0%
Costs:								
Broadband Cost	$ 36	$ 36	$ 36	$ 36	$ 36	$ 36	$ 36	$ 36
Dial-up Cost	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20
Second Phone Line Cost	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20
Converts:								
% Converts	100%	100%	100%	100%	100%	100%	100%	100%
# Second Lines	23,600,000	26,200,000	26,300,000	18,400,000	16,000,000	13,800,000	12,100,000	10,500,000
∆ in Second Lines		2,600,000	100,000	(7,900,000)	(2,400,000)	(2,200,000)	(1,700,000)	(1,600,000)
% Converts Dropping Second Phone line	0%	0%	0%	33%	33%	33%	33%	33%
Average Convert Saving from Dropped Line	-	-	-	$ 6.60	$ 6.60	$ 6.60	$ 6.60	$ 6.60
Additional Benefit of Broadband	$ 26	$ 26	$ 26	$ 26	$ 26	$ 26	$ 26	$ 26
Calculations:								
Total Household Adopters	35,490,000	43,990,000	53,821,000	56,700,000	59,514,000	66,000,000	73,260,000	81,760,000
Total Broadband Adopters	945,000	3,180,000	9,630,000	12,960,000	18,530,000	27,500,000	41,070,000	47,040,000
Total Dial-up Adopters	34,545,000	40,810,000	44,191,000	43,740,000	40,984,000	38,500,000	32,190,000	34,720,000
New Broadband Users	945,000	2,235,000	6,450,000	3,330,000	5,570,000	8,970,000	13,570,000	5,970,000
New Dial-up to Broadband Converts	945,000	2,235,000	6,450,000	3,330,000	5,570,000	8,970,000	13,570,000	5,970,000
Broadband Adopters (New Internet Users)	-	-	-	-	-	-	-	-
Cumulative Dial-up to Broadband Converts	945,000	3,180,000	9,630,000	12,960,000	18,530,000	27,500,000	41,070,000	47,040,000
Cumulative Broadband Adopters (NIU)	-	-	-	-	-	-	-	-
Annual Broadband Revenue	$ 408,240,000	$ 1,373,760,000	$ 4,160,160,000	$ 5,598,720,000	$ 8,004,960,000	$ 11,880,000,000	$ 17,742,240,000	$ 20,321,280,000
Annual Dial-up Revenue	$ 8,290,800,000	$ 9,794,400,000	$ 10,605,840,000	$ 10,497,600,000	$ 9,836,160,000	$ 9,240,000,000	$ 7,725,600,000	$ 8,332,800,000
Broadband Converts Revenue (Annual ∆)	$ 408,240,000	$ 965,520,000	$ 2,786,400,000	$ 1,438,560,000	$ 2,406,240,000	$ 3,875,040,000	$ 5,862,240,000	$ 2,579,040,000
Broadband Adopters (NIU) Revenue (Annual ∆)	-	-	-	$ -	$ -	$ -	$ -	$ -
Cannibalized Dial-up Revenue	$ 226,800,000	$ 536,400,000	$ 1,548,000,000	$ 799,200,000	$ 1,336,800,000	$ 2,152,800,000	$ 3,256,800,000	$ 1,432,800,000
Retired Second Phone Line Revenue	-	-	-	$ 263,736,000	$ 441,144,000	$ 710,424,000	$ 1,074,744,000	$ 472,824,000
Total Conversion Cost	$ 226,800,000	$ 536,400,000	$ 1,548,000,000	$ 1,062,936,000	$ 1,777,944,000	$ 2,863,224,000	$ 4,331,544,000	$ 1,905,624,000
Additional Revenue from Broadband	**$ 181,440,000**	**$ 429,120,000**	**$ 1,238,400,000**	**$ 375,624,000**	**$ 628,296,000**	**$ 1,011,816,000**	**$ 1,530,696,000**	**$ 673,416,000**
Avg. Monthly Broadband Benefit for Converts	$ 10.00	$ 10.00	$ 10.00	$ 16.60	$ 16.60	$ 16.60	$ 16.60	$ 16.60
Implied Decline in Price for Converts	28%	28%	28%	46%	46%	46%	46%	46%
Annual Total Broadband Benefit (Converts)	**$ 113,400,000**	**$ 268,200,000**	**$ 774,000,000**	**$ 663,336,000**	**$ 1,109,544,000**	**$ 1,786,824,000**	**$ 2,703,144,000**	**$ 1,189,224,000**
Revenue + Consumer Surplus	**$ 294,840,000**	**$ 697,320,000**	**$ 2,012,400,000**	**$ 1,038,960,000**	**$ 1,737,840,000**	**$ 2,798,640,000**	**$ 4,233,840,000**	**$ 1,862,640,000**
Total Gross Benefits for Broadband Since 1999	**$ 294,840,000**	**$ 992,160,000**	**$ 3,004,560,000**	**$ 4,043,520,000**	**$ 5,781,360,000**	**$ 8,580,000,000**	**$ 12,813,840,000**	**$ 14,676,480,000**

Broadband Bonus - Aggressive Case

Year	1999	2000	2001	2002	2003	2004	2005	2006
Assumptions:								
Usage Rates:								
Households	105,000,000	106,000,000	107,000,000	108,000,000	109,000,000	110,000,000	111,000,000	112,000,000
Overall Internet Adoption	33.8%	41.5%	50.3%	52.5%	54.6%	60.0%	66.0%	73.0%
Broadband Adoption	0.9%	3.0%	9.0%	12.0%	17.0%	25.0%	37.0%	42.0%
Dial-up Adoption	32.9%	38.5%	41.3%	40.5%	37.6%	35.0%	29.0%	31.0%
Costs:								
Broadband Cost	$ 36	$ 36	$ 36	$ 36	$ 36	$ 36	$ 36	$ 36
Dial-up Cost	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20
Second Phone Line Cost	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20
Converts:								
% Converts	81%	81%	81%	81%	81%	81%	81%	81%
# Second Lines	23,600,000	26,200,000	26,300,000	18,400,000	16,000,000	13,800,000	12,100,000	10,500,000
∆ in Second Lines		2,600,000	100,000	(7,900,000)	(2,400,000)	(2,200,000)	(1,700,000)	(1,600,000)
% Converts Dropping Second Phone line	0%	0%	0%	33%	33%	33%	33%	33%
Average Convert Saving from Dropped Line	-	-	-	$ 6.60	$ 6.60	$ 6.60	$ 6.60	$ 6.60
Additional Benefit of Broadband	$ 26	$ 26	$ 26	$ 26	$ 26	$ 26	$ 26	$ 26
Calculations:								
Total Household Adopters	35,490,000	43,990,000	53,821,000	56,700,000	59,514,000	66,000,000	73,260,000	81,760,000
Total Broadband Adopters	945,000	3,180,000	9,630,000	12,960,000	18,530,000	27,500,000	41,070,000	47,040,000
Total Dial-up Adopters	34,545,000	40,810,000	44,191,000	43,740,000	40,984,000	38,500,000	32,190,000	34,720,000
New Broadband Users	945,000	2,235,000	6,450,000	3,330,000	5,570,000	8,970,000	13,570,000	5,970,000
New Dial-up to Broadband Converts	765,450	1,810,350	5,224,500	2,697,300	4,511,700	7,265,700	10,991,700	4,835,700
Broadband Adopters (New Internet Users)	179,550	424,650	1,225,500	632,700	1,058,300	1,704,300	2,578,300	1,134,300
Cumulative Dial-up to Broadband Converts	765,450	2,575,800	7,800,300	10,497,600	15,009,300	22,275,000	33,266,700	38,102,400
Cumulative Broadband Adopters (NIU)	179,550	604,200	1,829,700	2,462,400	3,520,700	5,225,000	7,803,300	8,937,600
Annual Broadband Revenue	$ 408,240,000	$ 1,373,760,000	$ 4,160,160,000	$ 5,598,720,000	$ 8,004,960,000	$ 11,880,000,000	$ 17,742,240,000	$ 20,321,280,000
Annual Dial-up Revenue	$ 8,290,800,000	$ 9,794,400,000	$ 10,605,840,000	$ 10,497,600,000	$ 9,836,160,000	$ 9,240,000,000	$ 7,725,600,000	$ 8,332,800,000
Broadband Converts Revenue (Annual ∆)	$ 330,674,400	$ 782,071,200	$ 2,256,984,000	$ 1,165,233,600	$ 1,949,054,400	$ 3,138,782,400	$ 4,748,414,400	$ 2,089,022,400
Broadband Adopters (NIU) Revenue (Annual ∆)	77,565,600.00	261,014,400.00	790,430,400.00	$ 273,326,400	$ 457,185,600	$ 736,257,600	$ 1,113,825,600	$ 490,017,600
Cannibalized Dial-up Revenue	$ 183,708,000	$ 434,484,000	$ 1,253,880,000	$ 647,352,000	$ 1,082,808,000	$ 1,743,768,000	$ 2,638,008,000	$ 1,160,568,000
Retired Second Phone Line Revenue	-	-	-	$ 213,626,160	$ 357,326,640	$ 575,443,440	$ 870,542,640	$ 382,987,440
Total Conversion Cost	$ 183,708,000	$ 434,484,000	$ 1,253,880,000	$ 860,978,160	$ 1,440,134,640	$ 2,319,211,440	$ 3,508,550,640	$ 1,543,555,440
Additional Revenue from Broadband	**$ 224,532,000**	**$ 608,601,600**	**$ 1,793,534,400**	**$ 577,581,840**	**$ 966,105,360**	**$ 1,555,828,560**	**$ 2,353,689,360**	**$ 1,035,484,560**
Avg. Monthly Broadband Benefit for Converts	$ 10.00	$ 10.00	$ 10.00	$ 15.35	$ 15.35	$ 15.35	$ 15.35	$ 15.35
Implied Decline in Price for Converts	28%	28%	28%	43%	43%	43%	43%	43%
Annual Total Broadband Benefit (Converts)	**$ 91,854,000**	**$ 217,242,000**	**$ 626,940,000**	**$ 496,713,190**	**$ 830,838,578**	**$ 1,337,993,186**	**$ 2,024,143,538**	**$ 890,503,826**
Revenue + Consumer Surplus	**$ 316,386,000**	**$ 825,843,600**	**$ 2,420,474,400**	**$ 1,074,295,030**	**$ 1,796,943,938**	**$ 2,893,821,746**	**$ 4,377,832,898**	**$ 1,925,988,386**
Total Gross Benefits for Broadband Since 1999	**$ 316,386,000**	**$ 1,142,229,600**	**$ 3,562,704,000**	**$ 4,636,999,030**	**$ 6,433,942,968**	**$ 9,327,764,714**	**$ 13,705,597,613**	**$ 15,631,585,999**

Simulations: $40 Cases

Broadband Bonus - Base Case

Year	1999	2000	2001	2002	2003	2004	2005	2006
Assumptions:								
Usage Rates:								
Households	105,000,000	106,000,000	107,000,000	108,000,000	109,000,000	110,000,000	111,000,000	112,000,000
Overall Internet Adoption	33.8%	41.5%	50.3%	52.5%	54.6%	60.0%	66.0%	73.0%
Broadband Adoption	0.9%	3.0%	9.0%	12.0%	17.0%	25.0%	37.0%	42.0%
Dial-up Adoption	32.9%	38.5%	41.3%	40.5%	37.6%	35.0%	29.0%	31.0%
Costs:								
Broadband Cost	$ 40	$ 40	$ 40	$ 40	$ 40	$ 40	$ 40	$ 40
Dial-up Cost	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20
Second Phone Line Cost	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20
Converts:								
% Converts	100%	100%	100%	81%	81%	81%	81%	81%
# Second Lines	23,600,000	26,200,000	26,300,000	18,400,000	16,000,000	13,800,000	12,100,000	10,500,000
Δ in Second Lines		2,600,000	100,000	(7,900,000)	(2,400,000)	(2,200,000)	(1,700,000)	(1,600,000)
% Converts Dropping Second Phone line	0%	0%	0%	33%	33%	33%	33%	33%
Average Convert Saving from Dropped Line	-	-	-	$ 6.60	$ 6.60	$ 6.60	$ 6.60	$ 6.60
Additional Benefit of Broadband	$ 26	$ 26	$ 26	$ 26	$ 26	$ 26	$ 26	$ 26
Calculations:								
Total Household Adopters	35,490,000	43,990,000	53,821,000	56,700,000	59,514,000	66,000,000	73,260,000	81,760,000
Total Broadband Adopters	945,000	3,180,000	9,630,000	12,960,000	18,530,000	27,500,000	41,070,000	47,040,000
Total Dial-up Adopters	34,545,000	40,810,000	44,191,000	43,740,000	40,984,000	38,500,000	32,190,000	34,720,000
New Broadband Users	945,000	2,235,000	6,450,000	3,330,000	5,570,000	8,970,000	13,570,000	5,970,000
New Dial-up to Broadband Converts	945,000	2,235,000	6,450,000	2,697,300	4,511,700	7,265,700	10,991,700	4,835,700
Broadband Adopters (New Internet Users)	-	-	-	632,700	1,058,300	1,704,300	2,578,300	1,134,300
Cumulative Dial-up to Broadband Converts	945,000	3,180,000	9,630,000	12,327,300	16,839,000	24,104,700	35,096,400	39,932,100
Cumulative Broadband Adopters (NIU)	-	-	-	632,700	1,691,000	3,395,300	5,973,600	7,107,900
Annual Broadband Revenue	$ 453,600,000	$ 1,526,400,000	$ 4,622,400,000	$ 6,220,800,000	$ 8,894,400,000	$ 13,200,000,000	$ 19,713,600,000	$ 22,579,200,000
Annual Dial-up Revenue	$ 8,290,800,000	$ 9,794,400,000	$ 10,605,840,000	$ 10,497,600,000	$ 9,836,160,000	$ 9,240,000,000	$ 7,725,600,000	$ 8,332,800,000
Broadband Converts Revenue (Annual Δ)	$ 453,600,000	$ 1,072,800,000	$ 3,096,000,000	$ 1,294,704,000	$ 2,165,616,000	$ 3,487,536,000	$ 5,276,016,000	$ 2,321,136,000
Broadband Adopters (NIU) Revenue (Annual Δ)	-	-	-	$ 303,696,000	$ 507,984,000	$ 818,064,000	$ 1,237,584,000	$ 544,464,000
Cannibalized Dial-up Revenue	$ 226,800,000	$ 536,400,000	$ 1,548,000,000	$ 647,352,000	$ 1,082,808,000	$ 1,743,768,000	$ 2,638,008,000	$ 1,160,568,000
Retired Second Phone Line Revenue	-	-	-	$ 213,626,160	$ 357,326,640	$ 575,443,440	$ 870,542,640	$ 382,987,440
Total Conversion Cost	$ 226,800,000	$ 536,400,000	$ 1,548,000,000	$ 860,978,160	$ 1,440,134,640	$ 2,319,211,440	$ 3,508,550,640	$ 1,543,555,440
Additional Revenue from Broadband	**$ 226,800,000**	**$ 536,400,000**	**$ 1,548,000,000**	**$ 737,421,840**	**$ 1,233,465,360**	**$ 1,986,388,560**	**$ 3,005,049,360**	**$ 1,322,044,560**
Avg. Monthly Broadband Benefit for Converts	$ 6.00	$ 6.00	$ 6.00	$ 11.35	$ 11.35	$ 11.35	$ 11.35	$ 11.35
Implied Decline in Price for Converts	15%	15%	15%	28%	28%	28%	28%	28%
Annual Total Broadband Benefit (Converts)	**$ 68,040,000**	**$ 160,920,000**	**$ 464,400,000**	**$ 367,242,790**	**$ 614,276,978**	**$ 989,239,586**	**$ 1,496,541,938**	**$ 658,390,226**
Revenue + Consumer Surplus	**$ 294,840,000**	**$ 697,320,000**	**$ 2,012,400,000**	**$ 1,104,664,630**	**$ 1,847,742,338**	**$ 2,975,628,146**	**$ 4,501,591,298**	**$ 1,980,434,786**
Total Gross Benefits for Broadband Since 1999	**$ 294,840,000**	**$ 992,160,000**	**$ 3,004,560,000**	**$ 4,109,224,630**	**$ 5,956,966,968**	**$ 8,932,595,114**	**$ 13,434,186,413**	**$ 15,414,621,199**

Broadband Bonus - Conservative Case

Year	1999	2000	2001	2002	2003	2004	2005	2006
Assumptions:								
Usage Rates:								
Households	105,000,000	106,000,000	107,000,000	108,000,000	109,000,000	110,000,000	111,000,000	112,000,000
Overall Internet Adoption	33.8%	41.5%	50.3%	52.5%	54.6%	60.0%	66.0%	73.0%
Broadband Adoption	0.9%	3.0%	9.0%	12.0%	17.0%	25.0%	37.0%	42.0%
Dial-up Adoption	32.9%	38.5%	41.3%	40.5%	37.6%	35.0%	29.0%	31.0%
Costs:								
Broadband Cost	$ 40	$ 40	$ 40	$ 40	$ 40	$ 40	$ 40	$ 40
Dial-up Cost	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20
Second Phone Line Cost	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20
Converts:								
% Converts	100%	100%	100%	100%	100%	100%	100%	100%
# Second Lines	23,600,000	26,200,000	26,300,000	18,400,000	16,000,000	13,800,000	12,100,000	10,500,000
∆ in Second Lines		2,600,000	100,000	(7,900,000)	(2,400,000)	(2,200,000)	(1,700,000)	(1,600,000)
% Converts Dropping Second Phone line	0%	0%	0%	33%	33%	33%	33%	33%
Average Convert Saving from Dropped Line	-	-	-	$ 6.60	$ 6.60	$ 6.60	$ 6.60	$ 6.60
Additional Benefit of Broadband	$ 26	$ 26	$ 26	$ 26	$ 26	$ 26	$ 26	$ 26
Calculations:								
Total Household Adopters	35,490,000	43,990,000	53,821,000	56,700,000	59,514,000	66,000,000	73,260,000	81,760,000
Total Broadband Adopters	945,000	3,180,000	9,630,000	12,960,000	18,530,000	27,500,000	41,070,000	47,040,000
Total Dial-up Adopters	34,545,000	40,810,000	44,191,000	43,740,000	40,984,000	38,500,000	32,190,000	34,720,000
New Broadband Users	945,000	2,235,000	6,450,000	3,330,000	5,570,000	8,970,000	13,570,000	5,970,000
New Dial-up to Broadband Converts	945,000	2,235,000	6,450,000	3,330,000	5,570,000	8,970,000	13,570,000	5,970,000
Broadband Adopters (New Internet Users)	-	-	-	-	-	-	-	-
Cumulative Dial-up to Broadband Converts	945,000	3,180,000	9,630,000	12,960,000	18,530,000	27,500,000	41,070,000	47,040,000
Cumulative Broadband Adopters (NIU)	-	-	-	-	-	-	-	-
Annual Broadband Revenue	$ 453,600,000	$ 1,526,400,000	$ 4,622,400,000	$ 6,220,800,000	$ 8,894,400,000	$ 13,200,000,000	$ 19,713,600,000	$ 22,579,200,000
Annual Dial-up Revenue	$ 8,290,800,000	$ 9,794,400,000	$ 10,605,840,000	$ 10,497,600,000	$ 9,836,160,000	$ 9,240,000,000	$ 7,725,600,000	$ 8,332,800,000
Broadband Converts Revenue (Annual ∆)	$ 453,600,000	$ 1,072,800,000	$ 3,096,000,000	$ 1,598,400,000	$ 2,673,600,000	$ 4,305,600,000	$ 6,513,600,000	$ 2,865,600,000
Broadband Adopters (NIU) Revenue (Annual ∆)	-	-	-	$ -	$ -	$ -	$ -	$ -
Cannibalized Dial-up Revenue	$ 226,800,000	$ 536,400,000	$ 1,548,000,000	$ 799,200,000	$ 1,336,800,000	$ 2,152,800,000	$ 3,256,800,000	$ 1,432,800,000
Retired Second Phone Line Revenue	-	-	-	$ 263,736,000	$ 441,144,000	$ 710,424,000	$ 1,074,744,000	$ 472,824,000
Total Conversion Cost	$ 226,800,000	$ 536,400,000	$ 1,548,000,000	$ 1,062,936,000	$ 1,777,944,000	$ 2,863,224,000	$ 4,331,544,000	$ 1,905,624,000
Additional Revenue from Broadband	**$ 226,800,000**	**$ 536,400,000**	**$ 1,548,000,000**	**$ 535,464,000**	**$ 895,656,000**	**$ 1,442,376,000**	**$ 2,182,056,000**	**$ 959,976,000**
Avg. Monthly Broadband Benefit for Converts	$ 6.00	$ 6.00	$ 6.00	$ 12.60	$ 12.60	$ 12.60	$ 12.60	$ 12.60
Implied Decline in Price for Converts	15%	15%	15%	32%	32%	32%	32%	32%
Annual Total Broadband Benefit (Converts)	**$ 68,040,000**	**$ 160,920,000**	**$ 464,400,000**	**$ 503,496,000**	**$ 842,184,000**	**$ 1,356,264,000**	**$ 2,051,784,000**	**$ 902,664,000**
Revenue + Consumer Surplus	**$ 294,840,000**	**$ 697,320,000**	**$ 2,012,400,000**	**$ 1,038,960,000**	**$ 1,737,840,000**	**$ 2,798,640,000**	**$ 4,233,840,000**	**$ 1,862,640,000**
Total Gross Benefits for Broadband Since 1999	**$ 294,840,000**	**$ 992,160,000**	**$ 3,004,560,000**	**$ 4,043,520,000**	**$ 5,781,360,000**	**$ 8,580,000,000**	**$ 12,813,840,000**	**$ 14,676,480,000**

Broadband Bonus - Aggressive Case

Year	1999	2000	2001	2002	2003	2004	2005	2006
Assumptions:								
Usage Rates:								
Households	105,000,000	106,000,000	107,000,000	108,000,000	109,000,000	110,000,000	111,000,000	112,000,000
Overall Internet Adoption	33.8%	41.5%	50.3%	52.5%	54.6%	60.0%	66.0%	73.0%
Broadband Adoption	0.9%	3.0%	9.0%	12.0%	17.0%	25.0%	37.0%	42.0%
Dial-up Adoption	32.9%	38.5%	41.3%	40.5%	37.6%	35.0%	29.0%	31.0%
Costs:								
Broadband Cost	$ 40	$ 40	$ 40	$ 40	$ 40	$ 40	$ 40	$ 40
Dial-up Cost	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20
Second Phone Line Cost	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20	$ 20
Converts:								
% Converts	81%	81%	81%	81%	81%	81%	81%	81%
# Second Lines	23,600,000	26,200,000	26,300,000	18,400,000	16,000,000	13,800,000	12,100,000	10,500,000
∆ in Second Lines		2,600,000	100,000	(7,900,000)	(2,400,000)	(2,200,000)	(1,700,000)	(1,600,000)
% Converts Dropping Second Phone line	0%	0%	0%	33%	33%	33%	33%	33%
Average Convert Saving from Dropped Line	-	-	-	$ 6.60	$ 6.60	$ 6.60	$ 6.60	$ 6.60
Additional Benefit of Broadband	$ 26	$ 26	$ 26	$ 26	$ 26	$ 26	$ 26	$ 26
Calculations:								
Total Household Adopters	35,490,000	43,990,000	53,821,000	56,700,000	59,514,000	66,000,000	73,260,000	81,760,000
Total Broadband Adopters	945,000	3,180,000	9,630,000	12,960,000	18,530,000	27,500,000	41,070,000	47,040,000
Total Dial-up Adopters	34,545,000	40,810,000	44,191,000	43,740,000	40,984,000	38,500,000	32,190,000	34,720,000
New Broadband Users	945,000	2,235,000	6,450,000	3,330,000	5,570,000	8,970,000	13,570,000	5,970,000
New Dial-up to Broadband Converts	765,450	1,810,350	5,224,500	2,697,300	4,511,700	7,265,700	10,991,700	4,835,700
Broadband Adopters (New Internet Users)	179,550	424,650	1,225,500	632,700	1,058,300	1,704,300	2,578,300	1,134,300
Cumulative Dial-up to Broadband Converts	765,450	2,575,800	7,800,300	10,497,600	15,009,300	22,275,000	33,266,700	38,102,400
Cumulative Broadband Adopters (NIU)	179,550	604,200	1,829,700	2,462,400	3,520,700	5,225,000	7,803,300	8,937,600
Annual Broadband Revenue	$ 453,600,000	$ 1,526,400,000	$ 4,622,400,000	$ 6,220,800,000	$ 8,894,400,000	$ 13,200,000,000	$ 19,713,600,000	$ 22,579,200,000
Annual Dial-up Revenue	$ 8,290,800,000	$ 9,794,400,000	$ 10,605,840,000	$ 10,497,600,000	$ 9,836,160,000	$ 9,240,000,000	$ 7,725,600,000	$ 8,332,800,000
Broadband Converts Revenue (Annual ∆)	$ 367,416,000	$ 868,968,000	$ 2,507,760,000	$ 1,294,704,000	$ 2,165,616,000	$ 3,487,536,000	$ 5,276,016,000	$ 2,321,136,000
Broadband Adopters (NIU) Revenue (Annual ∆)	86,184,000.00	290,016,000.00	878,256,000.00	$ 303,696,000	$ 507,984,000	$ 818,064,000	$ 1,237,584,000	$ 544,464,000
Cannibalized Dial-up Revenue	$ 183,708,000	$ 434,484,000	$ 1,253,880,000	$ 647,352,000	$ 1,082,808,000	$ 1,743,768,000	$ 2,638,008,000	$ 1,160,568,000
Retired Second Phone Line Revenue	-	-	-	$ 213,626,160	$ 357,326,640	$ 575,443,440	$ 870,542,640	$ 382,987,440
Total Conversion Cost	$ 183,708,000	$ 434,484,000	$ 1,253,880,000	$ 860,978,160	$ 1,440,134,640	$ 2,319,211,440	$ 3,508,550,640	$ 1,543,555,440
Additional Revenue from Broadband	**$ 269,892,000**	**$ 724,500,000**	**$ 2,132,136,000**	**$ 737,421,840**	**$ 1,233,465,360**	**$ 1,986,388,560**	**$ 3,005,049,360**	**$ 1,322,044,560**
Avg. Monthly Broadband Benefit for Converts	$ 6.00	$ 6.00	$ 6.00	$ 11.35	$ 11.35	$ 11.35	$ 11.35	$ 11.35
Implied Decline in Price for Converts	15%	15%	15%	28%	28%	28%	28%	28%
Annual Total Broadband Benefit (Converts)	**$ 55,112,400**	**$ 130,345,200**	**$ 376,164,000**	**$ 367,242,790**	**$ 614,276,978**	**$ 989,239,586**	**$ 1,496,541,938**	**$ 658,390,226**
Revenue + Consumer Surplus	**$ 325,004,400**	**$ 854,845,200**	**$ 2,508,300,000**	**$ 1,104,664,630**	**$ 1,847,742,338**	**$ 2,975,628,146**	**$ 4,501,591,298**	**$ 1,980,434,786**
Total Gross Benefits for Broadband Since 1999	**$ 325,004,400**	**$ 1,179,849,600**	**$ 3,688,149,600**	**$ 4,792,814,230**	**$ 6,640,556,568**	**$ 9,616,184,714**	**$ 14,117,776,013**	**$ 16,098,210,799**